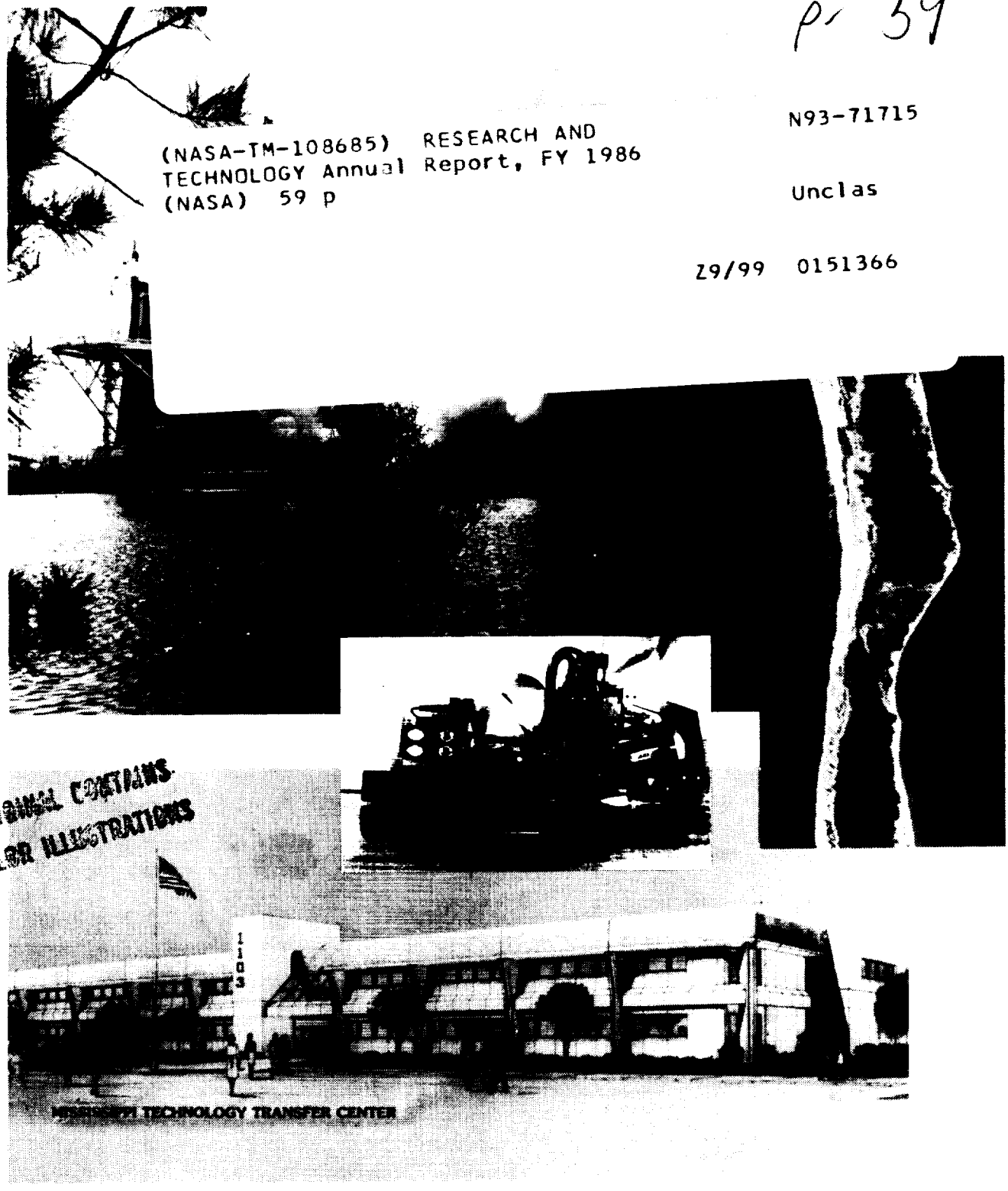
RESEARCH and TECHNOLOGY

NASA
National Aeronautics and Space Administration

National Space Technology Laboratories



ANNUAL REPORT **FY1986**

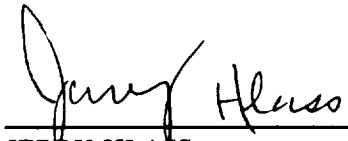
ABOUT THE COVER

Like the cover on this Annual Report, the National Space Technology Laboratories is a montage of diverse images. Astronauts see NSTL as a place where the Shuttle main engines, on which their success and their lives depend, are tested and proven safe and reliable. Sensor engineers see it as a place with the expertise to design and build a unique Calibrated Airborne Multispectral Scanner that can capture a stark but revealing image of a narrow Gulf Coast island, or a colorful and equally revealing image of a city in Kansas (see color plate). And industry is beginning to see NSTL as a source of technology that can be applied to everyday business needs and problems. These and many other images form a picture of what NASA has called a "High-Tech Mecca in the Deep South."

PREFACE

The purpose of this report is to present the accomplishments of the National Space Technology Laboratories R&T Program for Fiscal Year 1986.

The report includes program activities sponsored by the NASA Offices of Space Science and Applications, Space Flight, Space Station, Management, and Commercial Programs.



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For additional information on each R&T subject discussed in this report, refer to the Appendix, which gives the NSTL technical contact and telephone number.

CONTENTS

INTRODUCTION

INTRODUCTION

This annual report presents the accomplishments in research and technology of the National Space Technology Laboratories (NSTL) for Fiscal Year 1986. The report is divided into five major sections covering sensor research and development, commercial programs, earth sciences research, data systems engineering, and technology development and utilization programs.

The NSTL mission in remote sensing research and technology is directly supported by the Earth Resources Laboratory (ERL). Program activities in support of remote sensing are as follows:

- Scientific research to gain a better understanding of earth processes which lead to physical, chemical, and biological changes of the earth.
- Design, development, and testing of advanced airborne sensor systems and instrumentation.
- Development and utilization of state-of-the-art image analysis hardware and software systems.
- Development and utilization of a relational data base management system for a prototype global resources information system.
- Design and development of a payload software system, written in Ada programming language, to simulate data in Space Station formats for use in checkout of the Space Station Data System.
- Design and development of a distributed computer system for processing asynchronous data from up to seven environmental satellites simultaneously. The acquisition of this system will upgrade the Navy's Satellite Data Processing Center at Monterey, California.

In sensor research and development the Earth Resources Laboratory completed the development of a Calibrated Airborne Multispectral Scanner (CAMS). The CAMS represents a major advance in airborne systems, as it contains onboard reference sources which provide calibration information for the visible, short-wavelength infrared, and thermal infrared regions of the spectrum sampled, a capability lacking in nearly all operational systems to date.

The ERL Optics Laboratory will complete in December 1986 the fabrication of an Airborne Bathymetric System (ABS) for the Naval Ocean Research and Development Activity, and completed the design and initiated fabrication of an Airborne Multispectral Pushbroom Scanner (AMPS) for the Naval Oceanographic Office.

NSTL assumed major new initiatives during FY85 in support of NASA's Office of Commercial Programs, both in commercial space technology development and utilization. NASA selected the Mississippi Institute for Technology Development (ITD), to be located at NSTL, as one of two national Centers for the Commercial Development of Space (CCDS) research and technology in remote sensing. The ITD/CCDS began operation in the spring of 1986 and has made major strides in promoting partnership with industry and academia. In 1986 NSTL continued this support role to the CCDS and initiated an effort in direct support of the commercial sector by serving as a company account manager to support Office of Commercial Programs outreach programs.

In earth sciences research a major program in tropical forest change detection was continued in Puerto Rico and Costa Rica. The ecological stratificaton of tropical forest communities was studied using Thematic Mapper (TM) and Thematic Mapper Simulator (TMS) data. Other topics included microwave studies of forest biomass and canopy structure, airborne laser investigations of forest canopy characteristics, and several studies of forest vegetation using the Thermal Infrared Multispectral Scanner (TIMS). Investigations in wetlands biogeochemical flux estimations, land-sea interface and exchange processes, and soil delineation continued.

The Data Systems Engineering Division of ERL continued the development of the Global Resources Information Database (GRID) with the United Nations Environment Programme (UNEP).

A major effort for ERL in FY86 was support of Johnson Space Center (JSC), Goddard Space Flight Center (GSFC), and Marshall Space Flight Center (MSFC) in the development of a payload simulator for the Space Station Data Management System testbed efforts. The payload simulator software was developed in the Ada programming language.

INTRODUCTION

The Automated Information Management (AIM) program at NSTL, which was initiated in FY85 with program funding and a phased implementaton plan, continued. Major advances in office automation were made in this reporting period.

The NSTL Installation Operations Office leads a Technology Development program to identify new and innovative R&D projects that support the Center's present and future missions. During FY86 a number of investigations were conducted in support of NSTL's major operational mission—testing and flight certification of the Space Shuttle Main Engine (SSME). FY86 projects supporting the program were analysis of liquid hydrogen boil-off recovery and utilization; evaluation of gaseous hydrogen detector systems; verification of the accuracy of calibration gas standards; evaluation of the potential presence of contaminants in the SSME high-pressure gas facility; and identification of cost-effective alternatives to the 7,000 incandescent indicator lamps in the SSME Test Control Centers.

The NSTL Technology Utilization program continued to develop a broad-based technical emphasis during FY86. A major effort was assisting in the establishment of the Mississippi Technology Transfer Office (MTTO) at NSTL. A highlight of the program was the $3.5 million funding for construction of the MTTO building. Upon completion, the building will be given to NASA by the State.

The Technology Utilization program office supported the NSTL Environmental Research Laboratory in research and technology investigations in biodegradation, stabilization, and/or detoxification of contaminants in water, soil, and air. Specific projects were investigation of foliage plants for removing indoor air pollutants; bioregeneration of activated carbon for biological upgrade of domestic waste water to potable water; and biological cleanup of a hazardous waste site. The NSTL environmental systems programs assisted industry, State, and city governments through ongoing scientific research and customization of NASA technology to address local and national pollution issues.

Assistance to the medical community in magnetic resonance imaging (MRI) was provided during the second year of a joint project between NSTL and the Kennedy Space Center (KSC). Using the Earth Resources Laboratory Applications Software (ELAS) digital image processing packages, scientists made significant advances in the automated analysis of MRI data. This work has expanded and in FY86 a cooperative effort with the Wilmer Eye Institute, which investigates problems associated with the partially blind, was initiated. This is a cooperative effort with the Ames Research Center and the medical profession.

REMOTE SENSING RESEARCH

- Introduction
- Calibrated Airborne Multispectral Scanner
- Airborne Bathymetric System Scanner
- Airborne Multispectral Pushbroom Scanner

REMOTE SENSING RESEARCH

REMOTE SENSING RESEARCH

INTRODUCTION

The Sensor Engineering and Optics Laboratory at NSTL/ERL allows for the design, fabrication, calibration, and maintenance of multispectral scanner systems in one location using a single optical system and multiple illumination sources. The laboratory continues to be upgraded, with a 900-square-foot expansion essentially completed in FY86 and a 4,500-square-foot addition planned for FY88. The Optics Lab provides technical support to the ERL's research and commercial programs while designing and fabricating new instruments to meet NASA and Department of Defense requirements.

During FY86, the Calibrated Airborne Multispectral Scanner (CAMS) acquired its first test flight data, which represents a major accomplishment for the Optics Laboratory. Fabrication of the Airborne Bathymetric System (ABS) instrument for the Naval Ocean Research and Development Activity (NORDA) continued and that scanner is close to completion; and fabrication of the Airborne Multispectral Pushbroom Scanner (AMPS) for the Naval Oceanographic Office (NOO) was initiated following a detailed design study. This instrument is scheduled for completion in January 1988.

In addition, the Thermal Infrared Multispectral Scanner (TIMS) was maintained in an operational status to support NASA scientific and reimbursable data acquisition missions. Probably the most visible of these was the international Hydrologic Atmospheric Pilot Experiment (HAPEX) Mission in Europe during the summer of 1986. The Thematic Mapper Simulator (TMS) was also maintained and operated until it was replaced by the CAMS.

Figure 1 shows missions that were flown by the TIMS, TMS, and CAMS during FY86. (Both CAMS missions shown were flown during functional check flights, but they resulted in useful data that were incorporated into ongoing studies.)

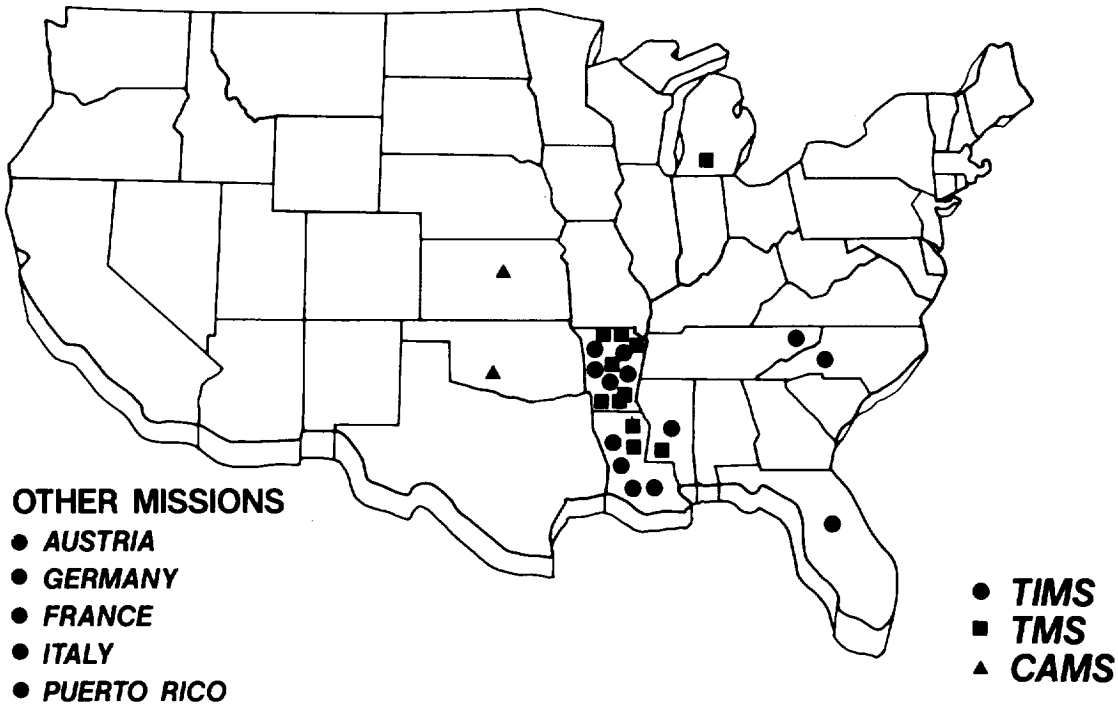


Figure 1. FY86 TIMS, TMS, and CAMS Missions

REMOTE SENSING RESEARCH

CALIBRATED AIRBORNE MULTISPECTRAL SCANNER

On August 1, 1986, the first CAMS engineering and evaluation functional check flight data were collected over Horn Island, off the Mississippi Gulf Coast (Figure 2). The CAMS represents a major advance in airborne sensor systems, as it contains onboard reference sources which provide calibration information for the visible, short-wavelength infrared, and thermal infrared regions of the spectrum sampled, a capability lacking in nearly all operational systems to date.

The CAMS is a nine-channel, airborne imaging device totally designed and fabricated by the Earth Resources Laboratory. Channels 1 through 9 sample electromagnetic energy in the following spectral regions (in micrometers): (1) 0.45–0.52, (2) 0.52–0.60, (3) 0.60–0.63, (4) 0.63–0.69, (5) 0.69–0.76, (6) 0.76–0.90, (7) 1.55–1.75, (8) 2.08–2.35, and (9) 10.5–12.5. Channels 1 through 6 utilize silicon detectors; Channel 7 employs a thermoelectrically cooled germanium detector; Channel 8 is based on a liquid-nitrogen-cooled, indium-antinomide detector; and Channel 9 uses a liquid-nitrogen-cooled, mercury-cadmium-telluride, trimetal detector. Scan speeds are adjustable from 6 to 80 scans per second in one-scan-per-second increments. Instantaneous field of view is set at 2.5 milliradians, with a total view angle of 100 degrees.

All channels of data contain information derived from onboard references. In the case of the visible and short-wavelength infrared channels, the reference is an 8-inch integrating sphere illuminated by a calibrated, 35-watt tungsten-halogen lamp. The thermal infrared channel makes use of two blackbody sources set at known and controllable temperatures. During data acquisition, each reference source is viewed by the CAMS, and the appropriate information is recorded for later use by researchers for specific task-oriented analysis of CAMS data.

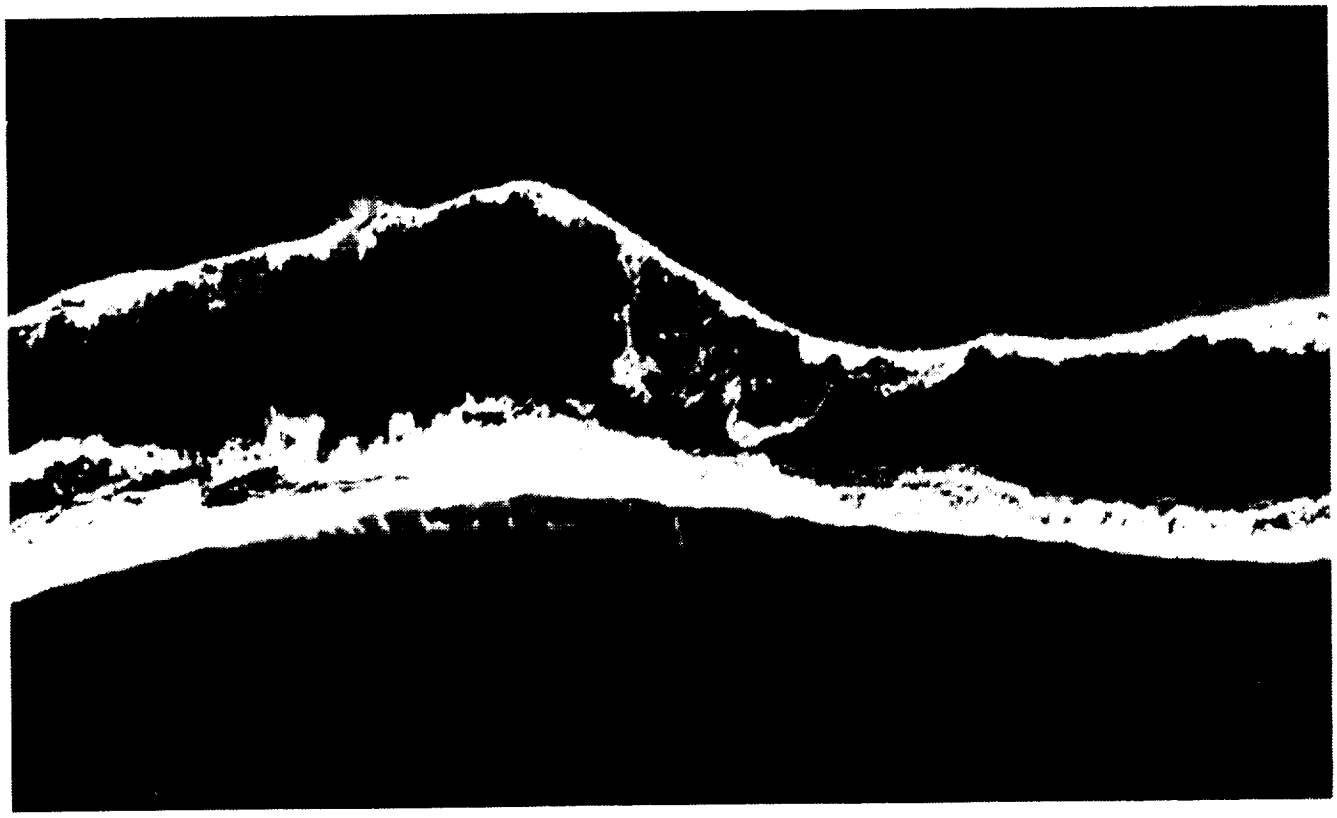


Figure 2. CAMS Channel 2 (0.52–0.60-Micrometer) Data Collected Over Horn Island, Mississippi, on August 1, 1986

Data recorded for each scan line during a mission include: blackbody temperatures (to nearest 0.1° C) time (in 0.01-second increments), latitude/longitude (to 0.1 minute), ground speed (to the nearest knot), true heading (to 0.1 degree), video (target) data (8-bit), blackbody video data, integrating sphere video data, channel gains/offsets, band edge information, and sensitivity. For a typical data acquisition mission at an altitude of 2 kilometers above terrain elevation, the pixel size is 5 meters on a side (at nadir), with an across-track coverage (within 30 degrees of nadir) of 2.33 kilometers.

The functional check flight resulted in data which were used to identify and isolate several problems in the sensor, and engineering personnel began correcting the anomalies late in FY86. (Later check flights over Kansas and Oklahoma yielded data of sufficiently high quality to be used in ongoing studies.) It is expected that the sensor system will be fully operational in the first quarter of FY87.

The image in the color plate on the next page was produced from CAMS data acquired over the First ISLSCP Field Experiment (FIFE) experimental area near Manhattan, Kansas. Flight and sensor parameters were specified to provide a nadir resolution of approximately 7.5 meters. The image shown is not geometrically corrected, but it does line up approximately north-south. Bands 3 (0.60–0.63 micrometer), 5 (0.69–0.76 micrometer), and 9 (8.0–11.0 micrometers) were composited to make the image. These are the bands that either are not present in the Thematic Mapper (TM) (Bands 3 and 5) or do not have the same spatial resolution (Band 9) as the TM. The data from each scan line were processed through a low-pass filter to subdue a high-frequency harmonic noise present in this early test data set. Careful study of the image will also show that Band 9 is not optically aligned with the other channels, a problem that has since been corrected. Features that can be readily identified include the campus of Kansas State University in the city of Manhattan and Interstate 70. Especially interesting is the strongly pronounced banding within the grasslands of the FIFE study area. This is interpreted to be geologic variations telegraphing through the overlying vegetation. The area was chosen in part because of its presumed uniformity.

AIRBORNE BATHYMETRIC SYSTEM SCANNER

Following several design and platform changes initiated by the Naval Ocean Research and Development Activity at NSTL, the ERL has completed design and almost completed fabrication of a new nine-channel scanner system to support NORDA's in-house R&D efforts. The Airborne Bathymetric System scanner is scheduled for delivery in mid-December 1986.

Channels 1 through 9 of the scanner collect electromagnetic energy in the following spectral regions (in micrometers): (1) 0.45–0.48, (2) 0.48–0.52, (3) 0.52–0.55, (4) 0.55–0.60, (5) 0.63–0.69, (6) 0.76–0.90, (7) 1.55–1.75, (8) 2.08–2.35, and (9) 10.4–12.5. Silicon detectors are used for Channels 1 through 6; Channel 7 uses germanium; Channel 8 utilizes indium-antinomide; and Channel 9 is a trimetal detector of mercury-cadmium-telluride. To maintain thermal equilibrium of the infrared detectors, the ABS scanner makes use of a dual-stage thermoelectric cooler on Channel 7, and closed cycle cryocoolers on Channels 8 and 9. This greatly reduces the ground support required and extends data acquisition time, since conventional liquid nitrogen dewars are eliminated. The unit has a 2-milliradian instantaneous field of view and a total scan angle of 90 degrees. Other specifications include:

Total scan angle	90°
Output data quantization	10 bits, with most significant 8 bits output
Scan speeds	10 to 160 revolutions per second, selectable in 1 RPS increments
Calibration:	
Visible-Short-Wavelength IR	Tungsten/halogen 8-inch integrating sphere
Thermal IR	2 blackbody sources

In preparation for system delivery, the ABS scanner visible array (Channels 1 through 6) will be placed into the CAMS scan head and flown on a data acquisition mission scheduled for mid-October 1986 over several offshore island areas. Concurrent ground truth will be collected, permitting NORDA to validate the effectiveness of software they will develop to estimate water depth based on the multispectral ABS sensor data. A preliminary visual analysis of CAMS data (particularly Channels 1 and 2, which cover the area of most significance

to NORDA) indicated that the potential for success is high (see Figure 2).

AIRBORNE MULTISPECTRAL PUSHBROOM SCANNER

In May 1985, the Naval Oceanographic Office commissioned NSTL/ERL to design, fabricate, and deliver a five-channel linear array pushbroom sensor, to be used for shallow-water bathymetry and for estimating depth to navigation hazards. The system has been designated the Airborne Multispectral Pushbroom Scanner, or AMPS.

Unlike most airborne sensors in use today, the AMPS relies on linear array technology to replace the rotating mirror and motor assembly of conventional optical/mechanical sensor systems. In this sensor, 512 separate detectors are arranged in line array fashion, each detector being 13 micrometers on each side. Target energy is focused through a specially designed lens system onto the array, and the individual detectors define the pixels along a "scan line." Onboard electronics are used to sample the voltages of each detector in the linear array, and these are converted to data values and stored on magnetic tape for subsequent processing and analysis.

The AMPS is configured in such a way that all five lens systems (one for each channel) are positioned along an axis that is parallel to the direction of flight. Electronic delayed sampling is used to provide channel-to-channel registration, and aircraft forward motion is used to define the next "scan line" on the ground. The AMPS is scheduled for delivery in January of 1988.

The five channels of the AMPS system acquire data in the following regions of the electromagnetic spectrum (in micrometers): (1) 0.45–0.49, (2) 0.49–0.52, (3) 0.52–0.55, (4) 0.55–0.58, and (5) 0.7–1.0. All channels use silicon detectors. Instantaneous field of view is 2 milliradians, with a scan angle of 58 degrees. Output data quantization is 12 bits. The detectors are Fairchild CCD153ADC linear array types (1 × 512 elements).

CALIBRATED AIRBORNE MULTISPECTRAL SCANNER

This CAMS image was produced from 7.5-meter data acquired over the FIFE experimental area near Manhattan, Kansas. Prominent features include the Kansas State University campus (A) and Interstate Highway 70 (B). Note the pronounced banding (C) in the FIFE study area grasslands, thought to be caused by geologic variations telegraphing through the overlying vegetation. This image is a composite of CAMS Bands 3, 5, and 9 (see text).

COMMERCIAL PROGRAMS

- Center for Commercial Development of Space Remote Sensing
- Space Station Commercial Utilization
- Large Format Camera

COMMERCIAL PROGRAMS

COMMERCIAL PROGRAMS

During FY86, NSTL/ERL began activities to promote the commercial development of space remote sensing. These activities are coordinated through the Office of Commercial Programs (OCP) and are currently composed of:

- Commercial research and development projects with the private sector and academia.
- Outreach activities, which focus on providing technical assistance to industry and preparing descriptive literature for the user community.
- Technical support to the Center for the Commercial Development of Space Remote Sensing.

Commercial remote sensing efforts are expected to accelerate at NSTL/ERL during FY87. An expanded outreach program involving coordination with several Industrial Applications Centers and the Office of Commercial Programs' User Development Contractor should result in new cooperative research projects with the private sector in sensor and system design.

ERL plans to serve in a company account manager role to support the OCP outreach program. Descriptive literature and presentation materials are key elements of ERL's commercial program. In FY86, ERL developed a brochure and a comprehensive panel display—depicting current program results and facilities—for the Oceans '86 Conference in Washington, D.C. ERL will continue to coordinate its outreach activities with OCP.

CENTER FOR COMMERCIAL DEVELOPMENT OF SPACE REMOTE SENSING

The State of Mississippi's Institute for Technology Development (ITD) established the National Center for Commercialization of Space Remote Sensing at NSTL in February 1986. The Space Remote Sensing Center (SRSC) focuses on business development, research and development, commercial projects, and training programs, with experienced professionals in charge of each of the four major functional categories.

The Center is operated by the ITD Space Remote Sensing Division at NSTL, and represents a major element of ITD's effort in technology transfer. Although the remote sensing effort is pursued at NSTL in close liaison with NSTL's Earth Resources Laboratory, ITD is a private corporation with a business-oriented operational philosophy.

In FY86, ITD established a viable Center operation with a business plan geared toward the general areas of land management, food and fiber, and, as secondary thrusts, minerals and oil, and mapping. Specific endeavors in spatial data management technology were initiated, and projects in agricultural crop assessment also were begun.

The Center is colocated with NSTL, and will move into a new $3.5 million facility provided by the State of Mississippi when construction is complete in the spring of 1987. The new facility is adjacent to the main office building occupied by NSTL/ERL. (See Technology Development and Utilization Programs Section.)

SPACE STATION COMMERCIAL UTILIZATION

NSTL/ERL continued Space Station planning activities concerned with the identification, development, and validation of commercial earth and ocean observation missions requirements. In close coordination with the Level B Customer Integration Office at Johnson Space Center (JSC), and in support of the Commercial Advocacy Group, NSTL has played a key role in defining and integrating commercial mission requirements for utilization of Space Station elements.

A national conference with international participation was held in Denver June 3 through 5. NSTL was the NASA coordinating center, and the conference was co-sponsored with National Oceanic and Atmospheric Administration (NOAA), Geosat Committee, Inc., ITD/Space Remote Sensing Center, Earth Observation Satellite Co. (EOSAT), and American Society of Photogrammetry and Remote Sensing. The conference was a resounding success, with more than 150 in attendance. Participants voiced their concerns and defined issues regarding commercial participation in the remote sensing element of the Space Station Program. These issues and concerns were prioritized during the conference and will be published as significant results in the conference proceedings, which are scheduled to be distributed in October 1986.

During FY86, the contract intermediary produced a final report providing a review of

current and developmental remote sensing instruments, a status of the remote sensing industry, and a comprehensive market analysis plan. This work will be continued and expanded under a new intermediary contract awarded in September 1986 to Teledyne Brown Engineering (TBE). As a business-oriented third-party intermediary, TBE will be supported by NASA Field Center technical expertise for important follow-up user requirements development. This task continues the implementation of a User Requirements Development Plan and involves interacting with industry on a continuing basis for assisting and developing interested operators/vendors/users. Areas of concern voiced by industry, including national security, legal, and fiscal issues and constraints, are also being investigated.

Based on the results of these activities, updates to the Space Station Mission Requirements Data Base (MRDB) were developed and implemented. These updates represent industry input to Space Station planning activities and are entered as "placeholders" for potential future commercial utilization of the core or polar platform elements. The current MRDB includes the following mission placeholders:

- COMM 1014, Remote Sensing Test, Development, and Verification Facility.
- COMM 1015, Large Format Camera.
- COMM 1019, Earth Resource Sensors.
- COMM 1020, Commercial SAR (Synthetic Aperture Radar).
- COMM 1023, Ocean Color Imager.

Technical support for these and other Space Station remote sensing activities is provided by the Commercial Earth and Ocean Observation Working Group (subgroup to the Commercial Advocacy Group), chaired by NSTL with members from Ames Research Center (ARC), Goddard Space Flight Center (GSFC), JSC, and Jet Propulsion Laboratory (JPL).

In addition, engineering expertise was provided to evaluate, plan, and establish requirements for commercial earth and ocean observation applications for the Space Station Mission Requirements Data Base. The GSFC-sponsored Space Station Users Working Group was supported with an NSTL representative to the Platform Panel. The Space Station Users Working Group provides input and guidance, from the users' perspective, to the Space Station design elements with the goal of producing a Space Station platform that will be functional and user friendly for all disciplines.

These activities will continue during FY87. In addition, a smaller workshop will be conducted by NASA/NSTL in late spring 1987 to continue the open forum interaction between industry and Government and to continue to get industry's requirements for space remote sensing in the Space Station era. The focus will be on defining and refining instrument envelopes based on industry's needs and data performance requirements. Comparative analysis of industry needs against current and planned sensors will be conducted to determine the feasibility and costs of dedicated and of shared instruments. Instrument payloads include multispectral imagers, mappers, radar systems, etc., which will be investigated for use by sole U.S. industry sponsors or as shared instruments for joint U.S. industry and Government missions or through international consortia.

LARGE FORMAT CAMERA

NASA/NSTL granted Martel Laboratories a license in December 1985 for the commercial distribution of Large Format Camera (LFC) imagery acquired during Shuttle Transportation System (STS) Mission 41-G. Sale and distribution of the high-resolution photography are being conducted through Chicago Aerial Survey, Inc., and Martel reports a brisk demand from domestic and international customers.

In addition, Autometric, Inc., was awarded a contract through NASA's Small Business Innovation Research (SBIR) Program (Phase II Solicitation) to study applications of LFC products. The contract, awarded in September 1986, includes the following tasks: evaluate and modify the stellar camera system, build a prototype workstation, document image exploitation procedures, develop a training program, and investigate the commercialization and marketing of the Large Format Camera system.

Martel's successful marketing of the LFC imagery has contributed to the development of a significant user group which is now using the imagery for a variety of earth science applications. Autometric's earlier study (SBIR Phase I Solicitation) investigated the potential civil and commercial applications of the LFC imagery. The LFC photographic and multispectral products were found to be viable supplements to other space and airborne multispectral systems

and to be economically competitive. Recently, industry has expressed strong interest in the leasing of the Large Format Camera for future Shuttle missions. These factors together demonstrate the potential for future LFC commercial ventures.

The LFC is the major component of NASA's Orbiter Camera Payload System (OCPS). Space Shuttle Challenger orbited the earth for 8 days—October 5 through 13, 1984—during Mission 41-G. The approximate altitude was 268 kilometers, with an orbital inclination of 57 degrees from the equator. The LFC offers high-resolution, relatively distortion-free stereoscopic imagery and a wide field of view. During the mission, the LFC collected 2,289 9- by 18-inch frames at a nominal scale of 1:850,000. Each frame encompasses an area approximately 120 by 240 nautical miles.

Figure 3 shows the Shuttle-unique Large Format Camera aboard Challenger during Mission 41-G.

Figure 3. Large Format Camera (White Cylinder) Is Visible Just Beyond Shuttle Imaging Radar (SIR-B) Antenna Being Checked by Astronaut Kathryn D. Sullivan During Mission 41-G

EARTH SCIENCES RESEARCH

- Tropical Forest Dynamics
  - Tropical Forest Change Detection
  - Ecological Stratification of Tropical Forest Communities
  - Microwave Studies of Forest Biomass and Canopy Structure
  - Airborne Laser Profiler Investigation of Forest Canopy Characteristics
- Forest Vegetation Thermal Studies
- C-Band Scatterometer for Forest Vegetation Characterization
- Forest Stress
- IRIS Studies
- Wetlands Productive Capacity Modeling
- Wetlands Biogeochemical Flux Estimation
- Land-Sea Interface
- Soil Delineation
- Archeological Studies
  - Costa Rica Archeology
  - Yucatan Archeology
- Urban Microclimate Study
- Geological Remote Sensing Research

EARTH SCIENCES RESEARCH

EARTH SCIENCES RESEARCH

The general goal of the earth sciences research program is to obtain a scientific understanding of the state and dynamics of global biological, chemical, and physical processes under natural and anthropogenic perturbations. Research is conducted by utilizing remotely sensed data acquired by a variety of sensors operated on a truck boom, on aircraft, and on spacecraft. Although some studies are site-specific, the overall objective is to gain information and knowledge that will enable modeling from a global perspective. Research is conducted through a team approach with a multidisciplinary staff. Preference is also given to developing joint research projects with university faculty or other external investigators in order to form teams that would be appropriate for the particular research objectives being addressed. In addition, collaborative research with external investigators is facilitated through the Resident Research Associateship Program administered through the National Research Council, the Summer Faculty Program, and a summer visiting scientist lecture program.

TROPICAL FOREST DYNAMICS

Portions of the following projects were conducted through Research and Technology Operating Plans (RTOPs) 677-21-33 and 688-37-00.

Tropical Forest Change Detection

NSTL's FY85 Annual Report described the long-term (1940 to 1983) relationships between forest clearing and landscape characteristics in Costa Rica, which were incorporated into a geographic data base. The data base was generated through the digitization of forest and landscape attributes derived from maps supplied by Costa Rican government agencies.

The use of the geographically referenced data base provided a tool to examine historical patterns of forest change at specific locations. One problem that was apparent in this preliminary study related to the generalized nature and small scales of the forest maps. Confidence levels could not be determined because the accuracies of the original forest maps were unknown. Also, the maps excluded information on forest regeneration and the distinction between total clearing and partial clearing (change from primary to disturbed forest classes). This type of information is needed to allow a complete assessment of the changing forest-land base.

Change detection techniques utilizing satellite-acquired data may provide the best means to monitor forest clearing and regrowth patterns. Historical patterns of change will be useful in directing satellite monitoring efforts to landscapes of predicted change (deforestation and afforestation). This is the goal of current research utilizing aircraft and satellite data collected over the Puerto Rico and Costa Rica study areas.

An example of a change detection image for an area in the vicinity of the La Selva Biological Reserve study site in Costa Rica is shown in Figure 4. Unsupervised classifications of 1976 and 1984 Landsat Multispectral Scanner (MSS) data were performed and spectral classes were grouped into forest and nonforest classes at each date.

The two classified images were combined to locate areas of deforestation and afforestation (natural secondary forest succession), and areas of no change. Gross changes in forest cover, as a percentage of the total area, included approximately 12% for the deforestation class and 5.5% for the secondary successional forest. Nearly all of the deforestation occurred on private land (left and right side of the image). The forest within La Selva Biological Reserve and the protection zone extending into Braulio Carrillo National Park (center portion of the image) was relatively undisturbed between 1976 and 1984. Points A and B are areas where secondary forest became established on land previously cleared for pasture.

The gross rate of deforestation has important implications for the conservation of flora and fauna in the region. For example, home ranges and migration routes for particular wildlife species can be severely impacted by the partial disturbance or total destruction of original forest in the area. The area of regenerating forest has important ramifications for studies in carbon storage and geochemical cycling, because secondary forests generally have higher growth rates and net primary production compared to mature or older growth forests. The release of carbon into the atmosphere through clearing of primary forest was partially offset by the accumulation of carbon in secondary forest. The net loss of forest cover was

Figure 4. Change Detection Image of La Selva Biological Reserve in Costa Rica

approximately 6.5% in this study area between 1976 and 1984.

More recent Thematic Mapper data (1986) are being analyzed to monitor forest changes between 1984 and 1986. Aerial photointerpretation and ground sampling techniques will be employed to evaluate the accuracy of satellite change detection and derive quantitative estimates with known confidence limits. A similar study of forest change and succession is being applied to a Puerto Rico test site.

Ecological Stratification of Tropical Forest Communities

There has been very little previous research in the tropical forests using multispectral scanners with the spectral and spatial resolutions equivalent to the Thematic Mapper (TM) and Thematic Mapper Simulator (TMS). Preliminary results of TMS investigations at Luquillo Experimental Forest in Puerto Rico indicated that the near infrared/red ratio technique improved the identification of four subtropical forest communities. For several sample areas selected, Sierra Palm (*Prestoea montana*) had the highest ratios, followed by the Tabonuco type, Palo Colorado type, and a dwarf community located near the ridge tops. These forest communities represent ecological gradients that are strongly influenced by elevation, climate, and soils.

Topographic stratification approaches are being investigated, along with channel ratioing techniques, to identify the location and extent of forest communities at Luquillo Experimental Forest. The last forest type map available for the Luquillo forest was prepared from 1951 black and white photography. Digitally combining terrain and remotely sensed data will facilitate the preparation of an updated type map of Luquillo species communities. A similar approach is being applied to a Costa Rica test site using TM and radar data combined with topographic and life zone (climatic) data.

Microwave Studies of Forest Biomass and Canopy Structure

Microwave (radar) sensors are of particular interest for tropical forest monitoring because active microwave systems can penetrate clouds and record the amount of energy returned from surface features. The multipolarized L-band (24.6 cm wavelength) synthetic aperture radar (SAR) system developed by the Jet Propulsion Laboratory can simultaneously transmit and receive like polarization (HH and VV) and cross-polarization (HV and VH) echo

signals (H and V represent Horizontal and Vertical). Investigations of forest canopies are important to understanding the potential role of microwave sensors for deriving estimates of forest biomass and vegetation structure.

A local test site was selected to evaluate forest biomass and radar measurements. Analysis of forest structure and biomass with multipolarization SAR data will facilitate the extension of the research into a tropical study site selected in Costa Rica.

The relationship of forest biomass, canopy structure, and species composition of L-band SAR data at 44 southern Mississippi bottomland hardwood and pine-hardwood forest sites was investigated. Multipolarization L-band SAR data were collected over the south Pearl River flood plain on September 11, 1984. The SAR data received from JPL were uncalibrated and were not corrected for gain in antenna pattern and range-induced variation. A scene illumination correction technique was applied. Also, the data were filtered (5 by 5 median value filter) and resampled to 30 meters (Figure 5).

Twenty pine and pine-hardwood stands and 24 hardwood-dominant sites were measured using point sampling forest inventory techniques. Twelve to 15 prism plots per site were sampled in even-aged pine stands and approximately 20 points were sampled in uneven-aged natural hardwood stands.

A computer program was used to apply locally developed regression equations to the field data. In addition, stand structure characteristics such as mean diameter at breast height (DBH), mean total height, mean basal area, and number of stems per hectare were computed for each forest measurement site. Mean digital values and standard deviations in each SAR polarization (excluding VH) were compared to the stand biomass and structure data for the 44 sample sites.

Best results were achieved in pine plantations, where significant linear relationships ($p = 0.05$) were observed between HV polarization and nearly all stand structure variables, including biomass (Figure 6). High soil moisture in poorly drained pine-hardwood stands appeared to influence SAR backscatter at lower incidence angles, especially when the forest canopies contained partial openings. Hardwood forest structure variables did not explain much of the variation with multipolarized SAR data when the variables were tested separately in linear regression analysis. Some of the relationships appeared to be nonlinear, particularly hardwood biomass versus SAR polarization response. The best results for correlating hardwood biomass were achieved at incidence angles between 34 and 41 degrees using HV polarization. High HV response and large standard deviation to mean digital values were recorded in structurally complex pine-hardwood and hardwood stands (Figures 6 and 7).

Comparisons of Figures 6 and 7 suggest a relationship between all forest types and HV radar data. The available data indicate an increase in radar return (expressed as a digital number, or DN) with increasing biomass up to approximately 100 tons/hectare. Above 100 tons/hectare the relationship becomes asymptotic; that is, a relatively constant DN with increasing biomass beyond 100 tons. Biomass at 100 tons/hectare or less was measured only in pine-dominant stands, while no pine stands greater than approximately 225 tons/hectare were measured. A horizontal line can be passed through the error bars of the other three forest types and the highest biomass point for the pine stands, where the relationship appears to follow the same trend. The same asymptotic relationship was observed using HH and VV polarization data. These data suggest that L-band radar was insensitive to biomass changes above approximately 100 tons/hectare.

Ratios of SAR polarization data, particularly HV/VV, improved the relationship with five hardwood stand structure variables in multiple linear regression (significance at $p = 0.01$). The VV polarization was shown to be correlated to mean DBH in hard-hardwoods, yielding a relatively high response, influenced by thick, heavy branching and high crown biomass (directly proportional to stem DBH). The HV/VV ratio may have helped to isolate some of the hardwood canopy geometric orientation properties that also existed independently in both the HV and VV polarization.

The techniques developed during the analysis of the Mississippi data set will be applied to L-band SAR data acquired through an aircraft mission over the Costa Rica study site. However, portions of the Costa Rica study site encompass rugged, mountainous terrain. Consequently, it was necessary to develop techniques through which the topographic effects can be modeled and, subsequently, removed from the SAR data. In order to facilitate this development, contour lines were digitized

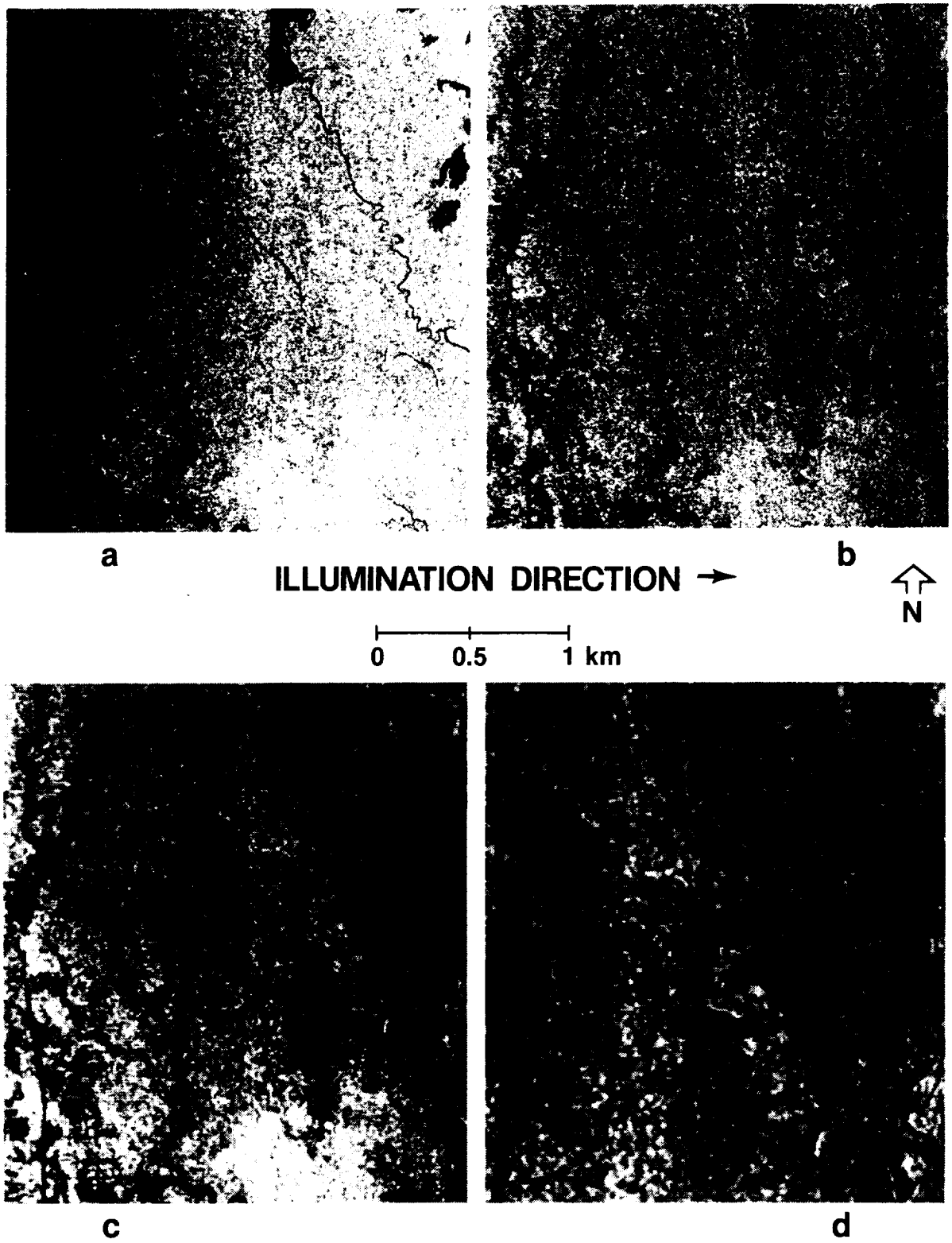


Figure 5. Sequence of L-Band Multipolarization SAR Preprocessed Images (Example of HV): (a) 10-Meter, Raw Data; (b) 10-Meter, Scene Illumination Corrected; (c) 10-Meter, Median Value Filtered; and (d) 30-Meter, Post-Filtered and Resampled

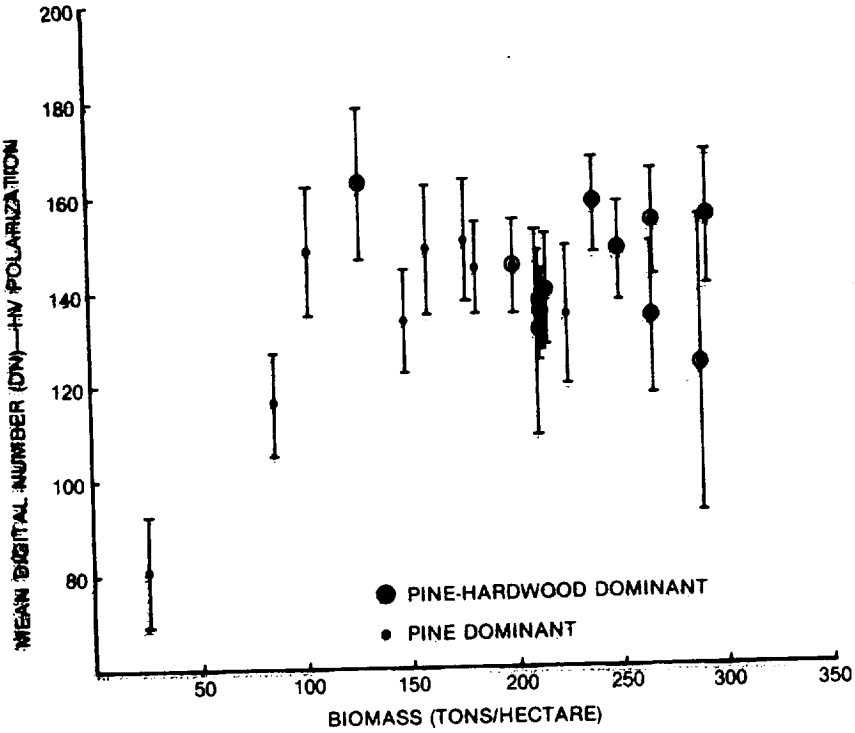


Figure 6. Estimated Biomass of Pine and Pine-Hardwood Stands and Mean DNs of HV Polarization Data with One Standard Deviation

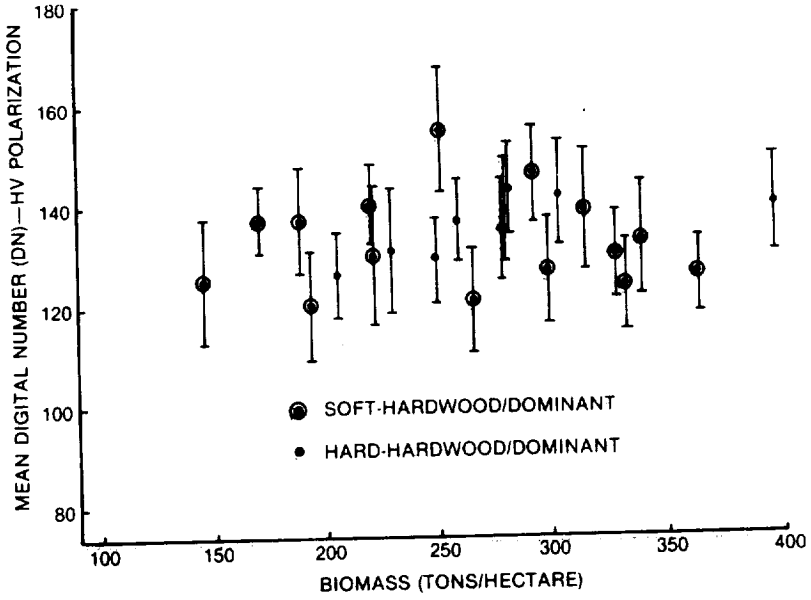


Figure 7. Estimated Biomass of Soft-Hardwood and Hard-Hardwood Dominant Stands and Mean DNs of HV Polarization Data with One Standard Deviation

from 1:50,000-scale (5-meter contour interval) maps available for the study area. Existing software was then used to derive information on elevation, aspect, and slope gradient, which was brought into a georeferenced data base to which the SAR data were also registered. Software that was developed to perform the topographic corrections is currently being tested. Analysis of the influence of above-ground biomass on SAR backscatter will be completed during FY87. The SAR data will also be analyzed to determine whether forest canopy structure changes with elevation can be discerned in the SAR data.

Airborne Laser Profiler Investigations of Forest Canopy Characteristics

Canopy height is an important measure needed to estimate forest volume and biomass. However, due to the "closed" nature of most tropical forest canopies, it is extremely difficult to make height measurements using aerial photograph parallax methods, as is possible in many temperate and boreal forests. For this reason, it is desirable to explore the use of sensors that allow a different approach to the measurement of tropical forest canopy height.

In October 1984, a laser profiler mission was flown over tropical canopies in Costa Rica using a neodymium YAG (yttrium aluminum garnet) system, operating at 400 pulses per second (wavelength 0.532 micrometer). The laser was mounted in a P-3A four-engine turboprop aircraft, flown at an altitude of 500 meters, with a ground speed of approximately 100 meters/second. A pulse was emitted approximately every 25 cm along the profile tract. When a

target (i.e., tree top) is illuminated, the pulse is reflected back and recorded by the sensor. Some pulses continue through the canopy and reach the terrain. Algorithms have been developed to plot the relative tree heights and terrain along the laser flight line. Aerial photography can be collected simultaneously with a 35 mm camera to provide a reference for the location of the laser track (Figure 8). The figure shows a black and white reproduction of a color infrared aerial photo (scale, 1:3,000), laser profiler data, and hypothetical profiles of terrain and forest types at La Selva Biological Reserve. The laser track (white line on photo) is shown crossing into the undisturbed, natural forest through the crown of a tree indicated by the number "1".

Differences in relative heights, crown diameters, and forest densities are apparent for the palm plantation, secondary forest, and primary forest shown in the figure. The terrain profile is well established in the palm plantation, where the evenly spaced, sparse canopy allowed sufficient openings for laser pulses to reach ground level. As the profiler continued into secondary and primary (mature) forest, very few pulses penetrated the dense canopies. The laser profile of the sloping terrain leading into primary forest was plotted as a smooth convex slope. The lack of sufficient "ground hits" in primary forest may misrepresent subtle variations or undulations in topography that may exist, as shown in the hypothetical drawing of the primary forest terrain profile. This undersampling of terrain reference points can introduce error into measurement of canopy height in dense tropical forests.

Field measurements have been collected along the laser track. Dominant tree heights in the primary forest were 38 to 42 meters, according to the field measurements. A large tree at the edge of the primary forest, identified by the number "1" on the aerial photo in Figure 8, was estimated from the laser data to be 36.5 meters in height. Ground measurements showed the tree was 39 meters tall.

Statistical comparisons of the field and laser measurements have been initiated. Some problems have been encountered in matching the laser data with ground-measured trees. The combination of the rugged terrain and the closed canopy causes great difficulty in pinpointing the locations of measured trees on the aerial photographs, and thus in the laser data. Work is continuing to resolve this problem.

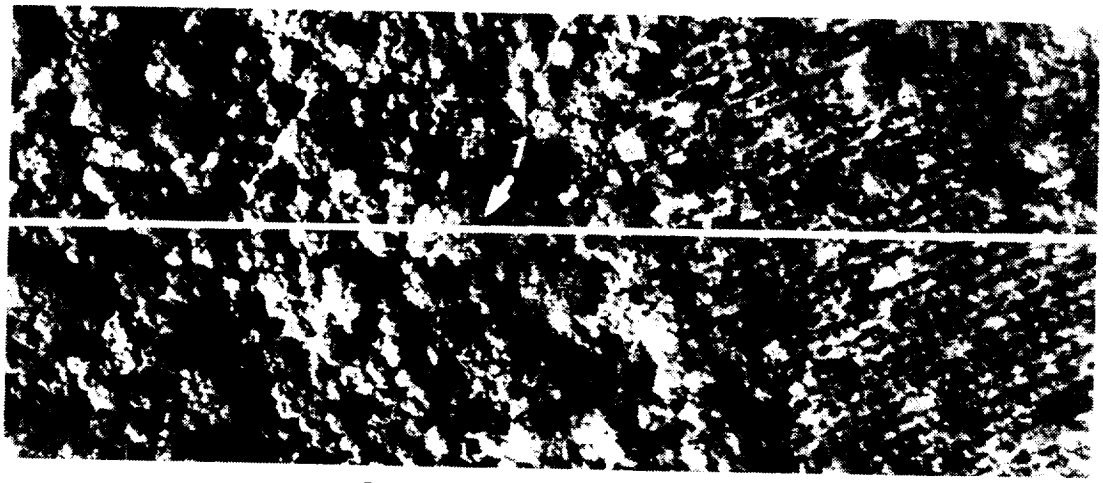
Information extraction from laser profiler data will require a considerable amount of additional testing to document the data's utility as a forest inventory tool. The variable terrain and dense forest canopies of tropical forest represent the most difficult conditions for conducting forest inventories, regardless of the methods employed.

FOREST VEGETATION THERMAL STUDIES

Since forest canopies exhibit diurnal changes in temperature related to incoming energy fluxes, detailed studies of their thermal responses are possible using the Thermal Infrared Multispectral Scanner (TIMS). In the past, such studies were limited to point measurements by instrumented towers at one or two locations within a forest. The TIMS allows investigators to compare the forest canopy thermal response of an entire forest watershed.

At the U.S. Forest Service's Coweeta Hydrologic Laboratory in North Carolina, white pine forest canopy temperatures obtained by the TIMS were compared to needle temperatures measured by thermocouples attached to needles. Three TIMS overflights were conducted to coincide with the daily energy cycle to examine the canopy thermal response (Figure 9). Agreement was excellent between needle thermocouple temperatures and TIMS canopy temperatures for the entire diurnal cycle (Table 1). Initial morning temperature differences between thermocouple and TIMS temperatures were caused by topographic shading of the canopy around the tower at low sun angles. Distribution of pixel temperature frequencies shifted to correspond with changes in the energy cycle (Figure 10). These findings lead to exciting uses for the TIMS in environmental plant physiology and landscape ecology. Additional work is in progress (RTOP 677-21-29) to model evapotranspiration from coniferous and hardwood forest canopies using surface temperatures obtained by the TIMS.

Another study is being conducted to determine the relationship between the temperatures of individual leaves and canopy temperature measured by the TIMS over a tropical forest. The ability to make canopy temperature measurements with the TIMS will facilitate studies of various temperature-related canopy physiological processes, such as nighttime respiration in tropical forests. A night TIMS mission was flown



SECONDARY FOREST

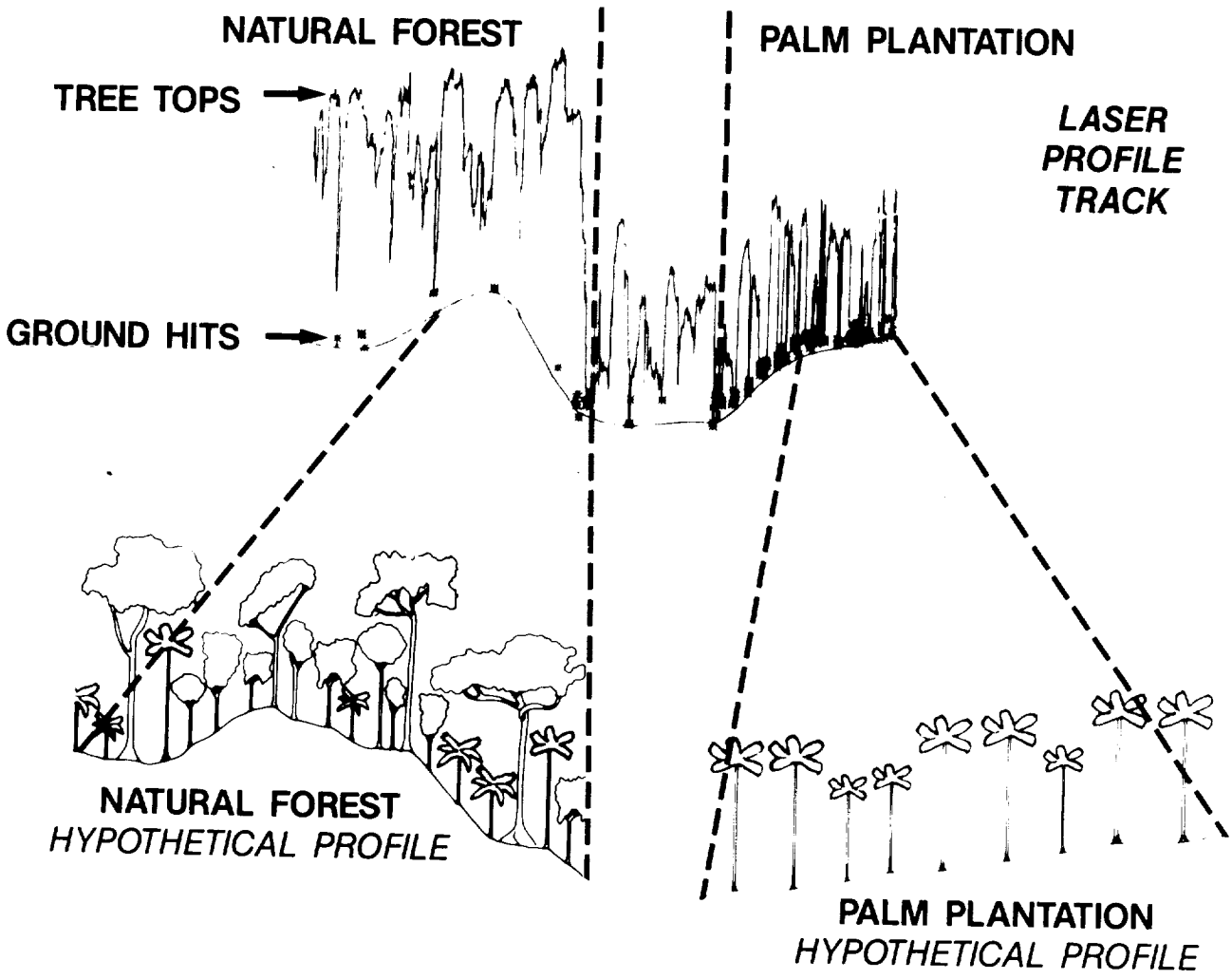


Figure 8. Laser Profiler Mission Data Sample

over instrumented towers in the Caribbean National Forest in Puerto Rico. Leaf temperatures were determined by fine-wire thermocouples attached to the leaves in the upper canopy. Results indicated that canopy temperatures measured by the TIMS are similar to individual leaf temperatures (Table 2).

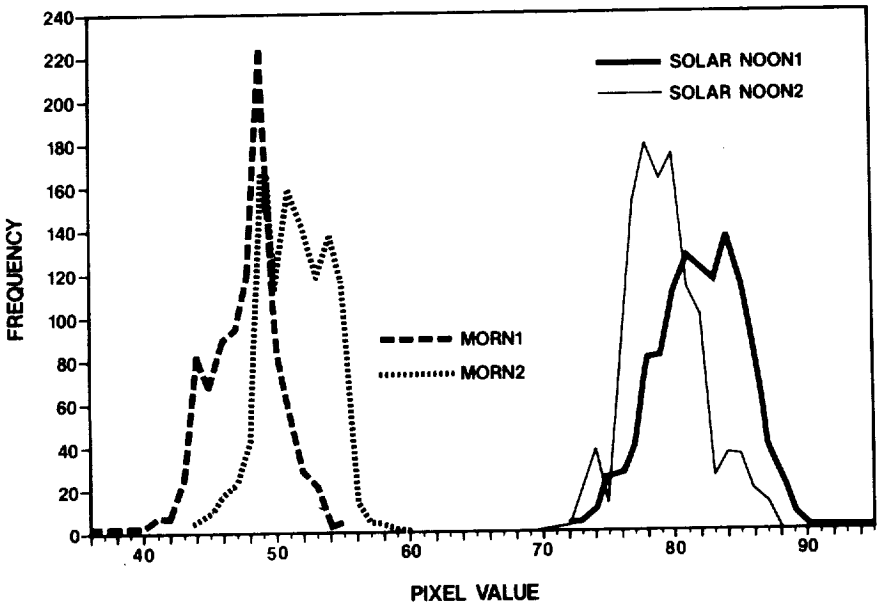


Figure 9. Coweeta White Pine Watershed Radiation Flux Density

Table 1
Comparison of Canopy Temperatures from TIMS and Needle Thermocouple Measurements

TIMS Flight	Time Ending (5-Minute Average)	Surface Temperature (°C) TIMS	Needle Thermocouple	Difference
Morning 1	0825	17.0	10.2	6.8
Morning 2	0855	18.0	12.2	5.8
Afternoon 1	1300	26.0	25.5	0.5
Afternoon 2	1325	25.0	25.9	−0.9
Night 1	1930	16.8	17.3	−0.5
Night 2	2000	16.4	16.6	−0.2

C-BAND SCATTEROMETER FOR FOREST VEGETATION CHARACTERIZATION

The objective of the C-band scatterometer field research (RTOP 677-27-18) is to investigate microwave backscatter and optical reflectance associated with forest canopy characteristics (e.g., height, density, morphology, and leaf water content). Research results are expected to provide a basis for developing models of forest structure to use in determining forest net primary productivity and biomass.

A paper on the preliminary results of the study was presented at the Institute of Electrical and Electronics Engineers (IEEE) 1985 International Geoscience and Remote Sensing Symposium (IGARSS '85). The paper, entitled "Preliminary Report on Measurements of Forest Canopies with C-Band Radar Scatterometer at NASA/NSTL," will be published in the November 1986 special IGARSS '85 issue of the IEEE Transactions on Geoscience and Remote Sensing. An updated paper was subsequently submitted to IEEE Transactions on Geoscience and Remote Sensing for publication in February 1987.

Field measurements were performed during March, April, and June of 1986 to investigate forest foliage changes during the growing season. Ten test plots were selected for this study. Tree species included live oak, red maple, black gum, cypress, and water oak. Data processing and analysis work will be completed by the end of November 1986 and the results submitted to a refereed journal.

FOREST STRESS

As part of an ongoing study to determine the relationship between forest stress and mycorrhizal fungi, sporophores have been inventoried periodically in two plots of Loblolly pine on a weekly basis. The 120- by 120-foot plots have 26-year-old trees at 10-foot spacings, resulting in 144 subplots. The two plots differ in that the seedlings of one plot received a single dose of N-P-K fertilizer at the age of one year. The total wood volume in the fertilized plots is now double that of the unfertilized plots. A greater diversity and biomass of mycorrhizal fungi occurred in the fertilized plots during each sampling period.

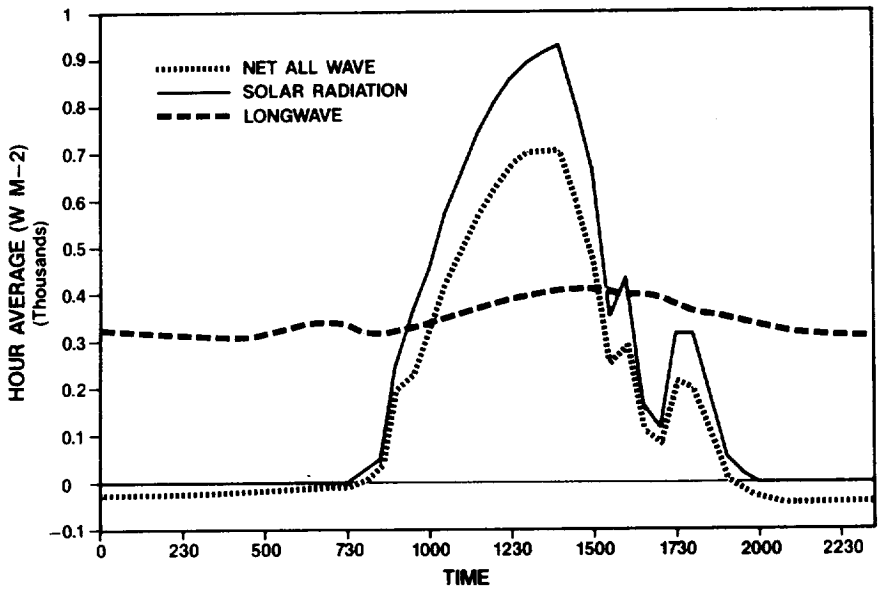


Figure 10. Coweeta White Pine Canopy Response

Table 2
Comparison of Canopy Temperatures Measured by TIMS and 15 Individual Thermocouples Attached to Upper Canopy Leaves

Flight	Time	Channel 2 Mean Deviation	Surface Temperature (°C) TIMS	Surface Temperature (°C) Leaf Thermocouple	Difference
PR361	1955	64	21.2	19.6	1.5
PR362	2017	63	21.0	20.7	0.3
PR363	2039	62	20.6	20.5	0.1
PR364	2046	61	20.4	19.0	1.4
Average					0.8

Registration of ratioed Thematic Mapper Simulator data (Channel 4/ Channel 3) with ground measurements of wood volume showed significant correlation (df = 167, r = 0.20, p ≈0.02). Both the ground-determined wood volume measurements and TMS data were acquiredwithin the same year (spring 1983).

The data from each subplot have been entered into a computer in such a manner that the spatial distribution of each species of mycorrhizal symbiont has been preserved. A seasonal or yearly sum of all collections, in which the spatial distribution is maintained, is calculated for each species. These same files are used with various statistical packages for further analysis both with respect to differing elements of field data and remotely acquired aircraft scanner data over these same areas. Details of the field data acquisitions have been reported (FY83 and FY84 NSTL Annual Reports).

Earlier, the 24-channel Multispectral Scanner and Data System (MSDS) was flown over this area. These data originally had a resolution of 8 feet, but during the georeferencing operation, they were resampled to a 10-foot resolution to correspond to the subplot resolutions used in the field sampling procedure. Unlike currently available MSS, TM, or TMS data, the MSDS scanner has

a channel sampling the spectral region in which chlorophyll changes its reflectivity from very low in the red to very high in the near-infrared (0.71–0.75 micrometer). To remove inconsistencies due to changes in illumination, a ratioed data set (Channel 9/ Channel 7) was prepared and placed in a georeferenced data base. When these ratioed data were compared with ground data of the spatial distribution of epigeous mycorrhizal species, significant relationships were observed for three species (Table 3). For comparison purposes, the field data represented the sum of three seasons' observations obtained both before and after the MSDS overflight. These observations suggest that there are significant differences in the 0.71–0.75 micrometer region which appear to be related to differences in canopy vigor; vigor is associated with mycorrhizal involvement with one or more of these three species.

Table 3
Correspondence Between Field Mycorrhizal Inventories and MSDS Remote Sensing Data (df = 142)

	MSDC Channel 9/ Channel 7 Ratio
AMFL, *Amanita flavoconia*	−0.17
AMRU, *Amanita rubescens*	−0.17
COSE, *Cortinarius semisanguineus*	−0.33
Total of All Mycorrhizal Species Observed	−0.26
ΣAMFL + AMRU + COSE	−0.34

The results of analysis of the MSDS data suggested that it would be desirable to obtain continuous, high-resolution spectra from needle clusters obtained from individual trees that, from field data, appear to differ in mycorrhizal involvement. Specific trees were chosen for study on the basis of the field studies—one tree was selected from an area of high sporophore occurrences and another from a region of significantly fewer sporophore occurrences.

With the cooperation of the U.S. Forest Service, a rifle was used to shoot out a branch from the uppermost canopy of each candidate tree in late April 1986. The excised stem of each branch was immediately placed in water and transported to NSTL for spectral measurement. This procedure does not cause physiological changes which could alter spectral data over the required time period (Gates, 1983, personal communications).

High-resolution spectral data were obtained with the Collins GER Intelligent Spectroradiometer (designated IRIS at ERL). Immediately before measurement, needles from each candidate branch were excised and positioned so that the target (sample) field of view as seen by this instrument was completely filled. A tungsten-halogen lamp was used as the illumination source in a laboratory setting, and polytetrafluoroethylene (PTFE) was used as the reference. Repeat runs demonstrated that no spectral changes occurred over a 15-minute time period with the excised needles.

Analyses of these spectra show significant differences between needle sets. The data led to the postulation of several nonvisual spectral changes which result from reduced mycorrhizal involvement: (1) reflectance reduction in the near-infrared plateau; (2) shift in position of red edge (~10 nm); (3) seasonal increases in the moisture stress index (reflection of ~1.65 micrometers divided by the reflection value at 1.25 micrometers); and (4) reduced leaf area index—less dense canopy in areas of low mycorrhizal involvement as detected by ratioed (infrared divided by red) data. These observations parallel those of Rock, et al. (1986), in areas of forest decline. Furthermore, Mohr (1985) suggests that damage to mycorrhizae from excess nitrogen deposition may be the most likely cause of forest decline.

In summary, these studies demonstrate that reduced mycorrhizal involvement can manifest itself with a suite of characteristics whose effects appear to be additive and which are measurable with remote sensing provided the data are acquired in specific wavelength regions.

IRIS STUDIES

The advent of high spectral resolution remote sensing instruments signals a new era in remote sensing technology which will dramatically increase the amount of earth resources information available to the remote sensing scientist. These new devices include the Airborne Imaging Spectrometer (AIS), the future Airborne Visible and Infrared Imaging Spectrometer (AVIRIS), the Shuttle-borne Shuttle Imaging Spectrometer Experiment (SISEX),

and the satellite-borne High Resolution Imaging Spectrometer (HIRIS).

The purpose of this project is to study the utility of the narrow bands eventually afforded by these sensors in vegetation stress and soil characterization investigations by simulating data with the portable Infrared Intelligent Spectroradiometer (IRIS). Vegetation stress was evaluated for a variety of wetland species as well as a number of southern pine species. The soils studied exhibited a wide variety of physicochemical properties.

The wetland plant phase of the IRIS investigation was composed of two parts: (1) a study of the spectral reflectance of cypress needles grown in hydroponic culture under different levels of salinity, nitrogen concentration, and redox potential; and (2) a survey of the spectral curves characteristic of 14 different wetland plant species collected over a salinity gradient of the Grand Bayou watershed in southwestern Louisiana. In all cases the IRIS spectral reflectance curves were measured under artificial illumination against a PTFE standard (the sample and standard were compared simultaneously, since the IRIS is a dual-beam instrument). The cypress needle experiment was conducted in order to detect plant stress, while the wetland plant investigation at Grand Bayou was designed to explore the feasibility of delineating different marsh salinity zones based on their characteristic spectral reflectance curves.

The IRIS sensor has been utilized to measure stress in a factorial experiment that varied salinity (five levels from 0.0 to 0.16 ppm NaCl), nitrogen concentration (three levels from 0.5 to 9 ppm), and aeration or nitrogen bubbling for plants grown in hydroponic culture. The experiment was conducted on cypress seedlings in cooperation with Dr. Irving Mendelssohn of the Center for Wetland Resources at Louisiana State University. In this experiment, healthy needles were observed at the lower salinity ranges which had anaerobic conditions and moderate nitrogen concentrations compared to stressed (lower growth rate and photosynthetic rate) needles at the higher salinity ranges grown under anaerobic conditions and lowest nitrogen levels. Brown cypress needles were gathered from dying or dead plants in the laboratory. It can be seen in Figure 11 that the spectral curve of dead cypress needles is quite different from that of the green needles or stressed needles. The stress in the cypress needles is manifested in the IRIS spectra by lower infrared peaks between the 800 and 1200 nm plateau and at the 1660 nm peak. Also, the visible/near-infrared boundary in stressed needles is displaced to the right of that in healthy needles (referred to as blue shift of red edge—Rock, et al., 1986).

The characteristic spectral reflectance curves of *Spartina alterniflora* (salt marsh dominant), *Spartina patens* (brackish marsh dominant), *Alternanthera philoxeroides* (intermediate marsh), and *Sagittaria falcata* (freshwater marsh) are illustrated in Figure 12. All of the curves have reflectance peaks at the green range in the visible wavelength spectrum and at three regions in the infrared spectrum. Each of the four plant species has a distinctive combination of spectral reflectance (the ordinate) values for each of these peaks and the shape of the infrared plateau varies within each species. The visible peak

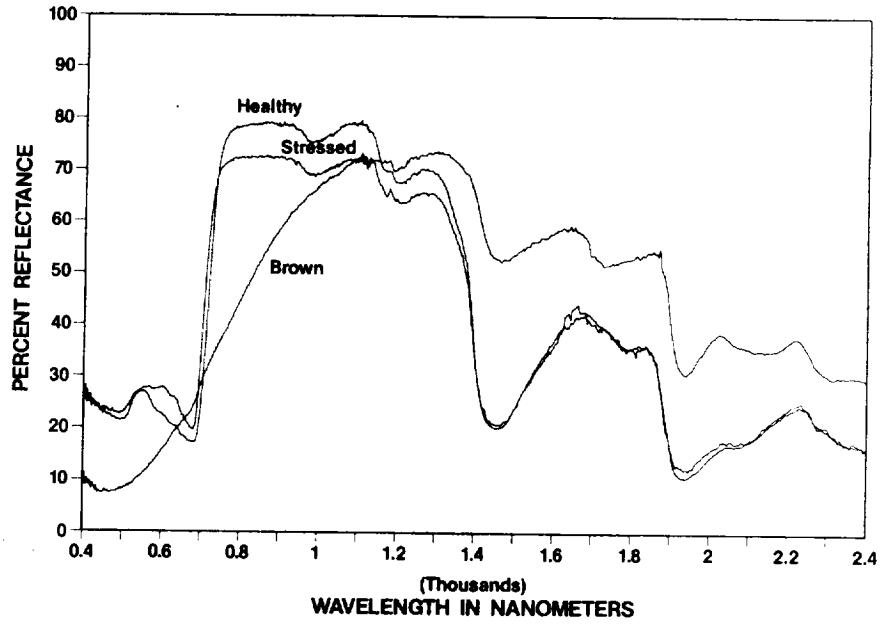


Figure 11. Comparison of Healthy, Stressed, and Dead Cypress Needles

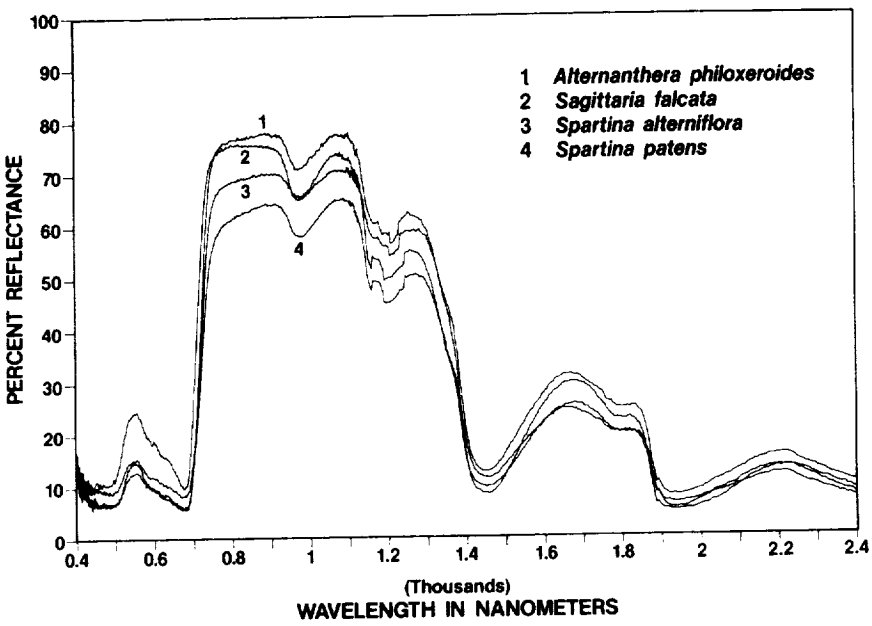


Figure 12. Comparison of Four Common Marsh Vegetation Species

corresponds to plant pigment differences; the infrared plateau to differences in cell structure; and the other two infrared peaks to variations in leaf water content (Rock, et al., 1986). Research in the productive capacity of wetlands project (see next subsection) using Thematic Mapper data was not able to separate the different marsh salinity zones at Grand Bayou, but the results with the IRIS suggest that high-resolution, multiband sensors such as the AVIRIS might be able to separate the different marsh salinity zones (barring unforeseen impacts of atmospheric effects on these airborne scanners).

Another phase of the IRIS study on vegetation stress investigated the impact of mycorrhizal involvement on Loblolly and Slash pine in a south Mississippi plantation operated by the U.S. Forest Service (see Forest Stress subsection). Branches from individual trees representing plots of low and high mycorrhizal activity were collected and needles excised from them for spectral analysis by the IRIS.

Spectra for the "stressed" pine needles (lower mycorrhizal activity) illustrate a reduced reflectance along the entire near-infrared plateau (from 0.775–1.2 micrometers, Figure 13) of the spectrum. This type of shift exhibited by both upland pine species and wetland plant species indicates that this phenomenon may be common to most plants experiencing stress.

The soils investigation phase of the IRIS project focused on two major parameters of importance in soils characterization: qualitative and quantitative determination of iron oxides and clays. The present Thematic Mapper system exhibits some potential for iron oxide characterization but very little for clay-type characterization due to placement of the mid-IR bands. IRIS and the aforementioned narrow-band remote sensors provide additional bands which will aid in these characterizations.

Highly hydrated iron oxides (e.g., goethite) appear yellow and exhibit minima most strongly in the 0.50–0.54 micrometer range, while less hydrated iron oxides (e.g., hematite) appear more reddish and exhibit their strongest minima in the 0.554–0.596 micrometer range. The spectra of the yellow compounds rise quickly after their minima while the reddish compounds maintain a slower rate of increase and even exhibit another more marked absorption around 0.9 micrometer than the highly hydrated forms. Total reflectances of highly hydrated forms are also substantially higher than for less hydrated forms (Figure 14). Soils low in organic matter and highly influenced by iron oxide would likewise exhibit similar trends in the visible region.

Different clays also exhibit different absorption minima. Montmorillonites are typified by strong absorption bands at 1.4 and 1.9 micrometers due to water, while kaolinite only has a weak minima at 1.9 micrometers. Kaolinite does, however, exhibit strong absorptions at 1.4 and 2.2 micrometers. Illites, on the other hand, exhibit low absorption intensities at these regions compared to either montmorillonite or kaolinite (Figure 15).

The significances of iron oxides and clays in soil characterization are several, including inferring soil development phase, parent material, fertility/productivity status, and erosional condition.

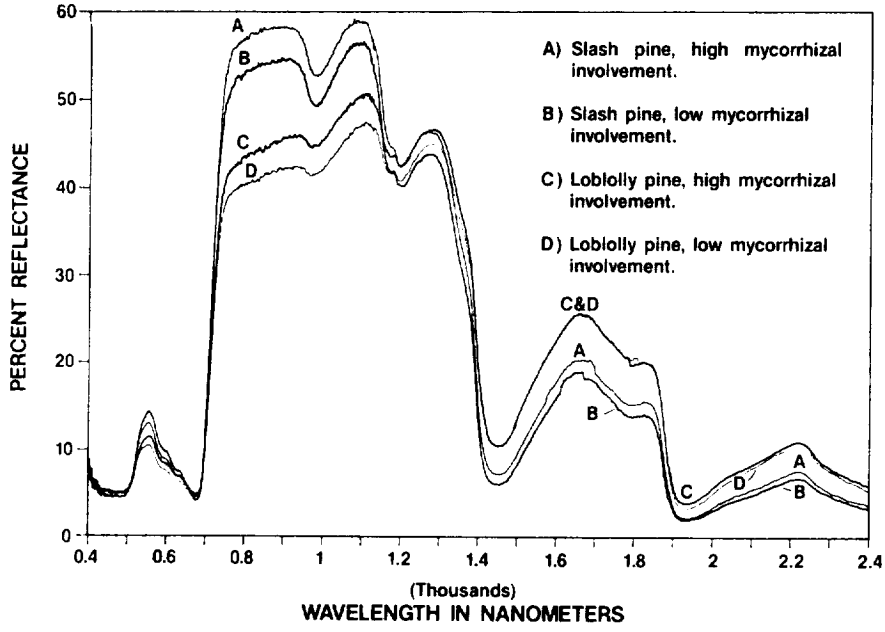


Figure 13. Reflective Properties of Loblolly and Slash Pine Needles Collected from Trees with Differing Degrees of Mycorrhizal Involvements (Note: In all cases, reduced mycorrhizal involvement causes a reduction in the infrared plateau as well as a slight "blue shift" in the reflective transitional region of the spectrum—0.69-0.74 micrometer.)

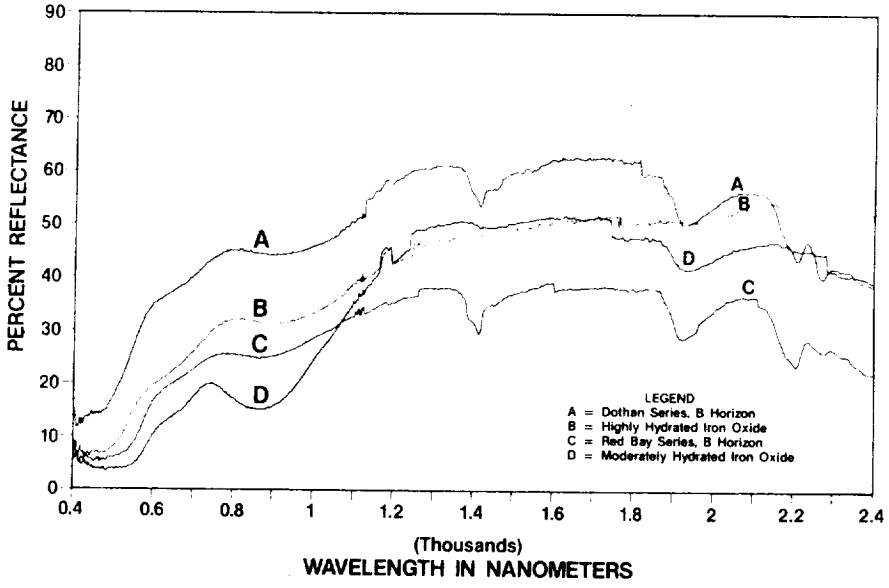


Figure 14. Comparison of Spectra for Limonite (Highly Hydrated Iron Oxide—Yellow), Hematite (Hydrated Iron Oxide—Red), Dothan Soil (Yellow), and Red Bay Soil (Red)

WETLANDS PRODUCTIVE CAPACITY MODELING

The Wetlands Productive Capacity Modeling Joint Research Project (RTOP 677-60-14) is a cooperative endeavor between NASA/NSTL/ERL and NOAA/NMFS/SEFC (National Oceanic and Atmospheric Administration/National Marine Fisheries Service/Southeast Fisheries Center). The goal of the project is to quantify the coupling between coastal wetland plant production and the yield of coastal fish and shellfish populations.

Analysis of the May 1984 and September 1984 TM scenes with the ELAS software modules designed for image processing indicated that freshwater, intermediate, and brackish marshes could not be separated from one another with sufficient accuracy with TM data collected on those dates. Heavy cloud cover prevented acquisition of TM data at times (early spring and late fall) that might have enabled investigators to separate the different marsh salinity zones. This approach to discerning the different marsh salinity zones is supportive of the "indirect method" (combining literature values of primary production with areal estimates of the extent of each marsh type) for estimating net aboveground primary production in the NASA Productive Capacity (PC) model.

The direct approach for estimating marsh biomass from TM digital data or indices derived from digital data has proven more encouraging than the indirect approach. Another part of this investigation was a comparison of TM digital data averaged over a 4- by 4-pixel (120- by 120-meter)

area with the average biomass sampled within a 4- by 4-pixel region on the ground. The results of this analysis are given in Tables 4 and 5. The results were more encouraging than those reported by Butera, et al. (1984), and Butera and Frick (1984). A number of significant regressions between biomass components and raw digital values (Table 4) or indices (Table 5) occur with correlation coefficients (R) near or above 0.70. From Table 4 it can be seen that Band 4 (near-infrared) is best for estimating live and live-on-dead biomass, while the visible bands (1 through 3) and mid-infrared bands (5 and 7) are best for estimating dead and total biomass. In Table 5, the vegetation index (Hardisky, et al., 1983) and Version A of the reflectance ratio (Curran, 1980) are best for estimating live biomass, while the infrared index (Hardisky, et al., 1983) and Version B of the reflectance ratio (Curran, 1980) give the best results for dead and total biomass.

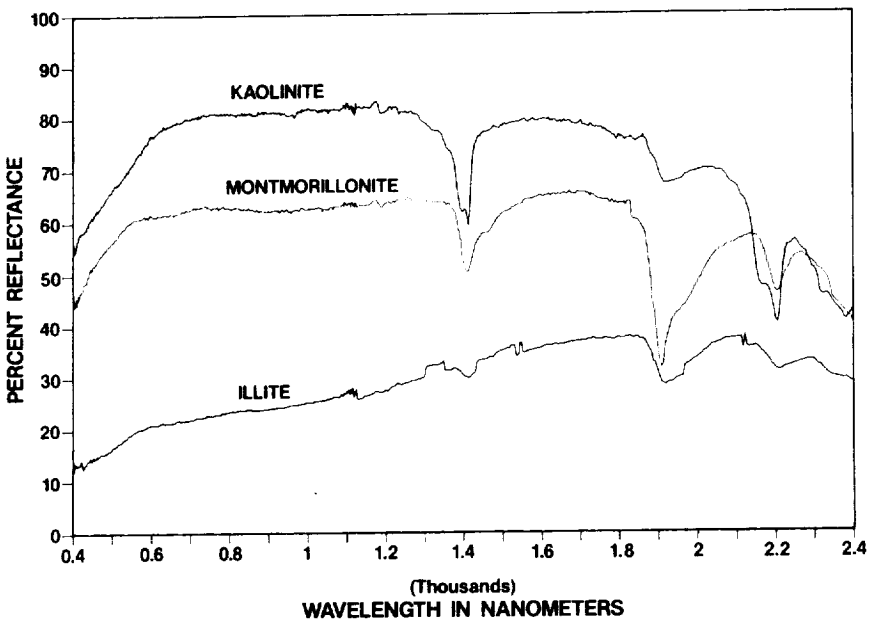


Figure 15. Comparison of Three Common Clay Types and Their Characteristic Water Absorption Minima

Table 4
Regressions of Marsh Plant Biomass Components Versus Raw Digital Count Data (May 1984)

Plant Component	Multiple R	Simple Regression (R) By Band 1	2	3	4	5	7
Live Weight	0.698*	−0.098	0.050	−0.129	0.502**	0.068	−0.065
Live on Dead	0.443	0.168	0.266	0.127	0.353**	0.170	0.094
Dead Weight	0.794*	0.747*	0.705*	0.767*	0.362**	0.766*	0.784*
Total Weight	0.755*	0.682*	0.704*	0.680*	0.523*	0.733*	0.699*

*Probability ≤0.01
**Probability ≤0.05

NOAA's Estuarine Ecosystem Energy Flow (EEEF) model has been altered as can be seen in Figure 16. In the revised model, all of the animal compartments (menhaden, shrimp, benthos, crabs, croaker, trout and drum, and zooplankton) feed back into the detritus compartment. In the earlier version of the EEEF model, only the phytoplankton fed back into the detritus compartment. This change will introduce non-linear behavior to the EEEF model. Another change in the model that is not apparent from the figure is that the initial conditions for each animal compartment have been changed. A sensitivity analysis of the model revealed that it was sensitive to the initial conditions and it was felt that a more accurate simulation could be achieved by altering the initial biomass levels in each animal compartment.

WETLANDS BIOGEOCHEMICAL FLUX ESTIMATION

This project is a joint effort being conducted by NSTL/ERL, Langley Research Center, and the National Park Service (NPS)

Table 5
Regressions of Marsh Plant Biomass Components Versus Selected Indices Generated by Combining Raw Digital Count Values

	Simple Regression (R) Coefficients			
			Reflectance Ratio	
Plant Component	Vegetation Index	Infrared Index	A	B
Live Weight	0.61*	0.36*	0.57*	0.12
Live On Dead	0.29	0.08	0.34**	0.18
Dead Weight	0.03	0.66*	0.23	0.75*
Total Weight	0.23	0.47*	0.42**	0.74*

*Probability ≤ 0.01
**Probability ≤ 0.05

$$\text{Vegetation Index} = \left[\left(\frac{\text{Band 4} - \text{Band 3}}{\text{Band 4} + \text{Band 3}}\right) \times 100\right] + 100.5$$

$$\text{Infrared Index} = \left[\left(\frac{\text{Band 4} - \text{Band 5}}{\text{Band 4} + \text{Band 5}}\right) \times 100\right] + 100.5$$

$$\text{Reflectance Ratio} = \frac{\text{Band 4}}{\text{Band 1} + \text{Band 2} + \text{Band 3}} \text{ (A) or}$$

$$\frac{\text{Band 5}}{\text{Band 1} + \text{Band 2} + \text{Band 3}} \text{ (B)}$$

South Florida Research Laboratory. The objectives are to: (1) examine the capabilities of current remote sensing instruments to delineate wetland vegetation types as prioritized by the Wetlands Research Working Group, and (2) develop and test a geographic information system, within the context of a pilot experiment, for estimating methane emissions from wetland ecosystems. The pilot experiment is being conducted in the Everglades National Park and is composed of two major tasks: (1) comparative analysis of Thematic Mapper, Multispectral Scanner, and Advanced Very High Resolution Radiometer (AVHRR) mapping results to determine the utility of each for biogeochemical studies, and (2) development of a spatial data base which combines geobased information (surface cover, inundation, temperature, salinity) with ground-based methane flux measurements to facilitate model development and testing.

During FY86, several subtasks were completed under RTOP 199-30-25, including:

- TM false color image of south Florida and surface cover map of Shark River Slough. The images were developed specifically for the pilot methane (CH_4) flux measurements and were provided to the field team for location and verification.

- MSS surface cover stratification of Everglades National Park with areal extent estimates of wetland types. These estimates were used in the modeling effort to calculate total flux.

- TM/MSS comparisons. TM and MSS data over selected test sites were registered and resampled to 25 meters. Map results were compared to determine effects of aggregation on map accuracy. Extensive field checks were made to determine accuracy of TM and MSS stratifications. Results indicated that TM was more accurate in mapping vegetation cover types because of increased spatial and spectral resolution.

- AVHRR surface cover stratification. The purpose of this activity was to determine the utility of AVHRR data for locating and measuring areal extent of wetland ecosystems on a regional or global scale and to determine if inundation boundaries can be monitored with AVHRR.

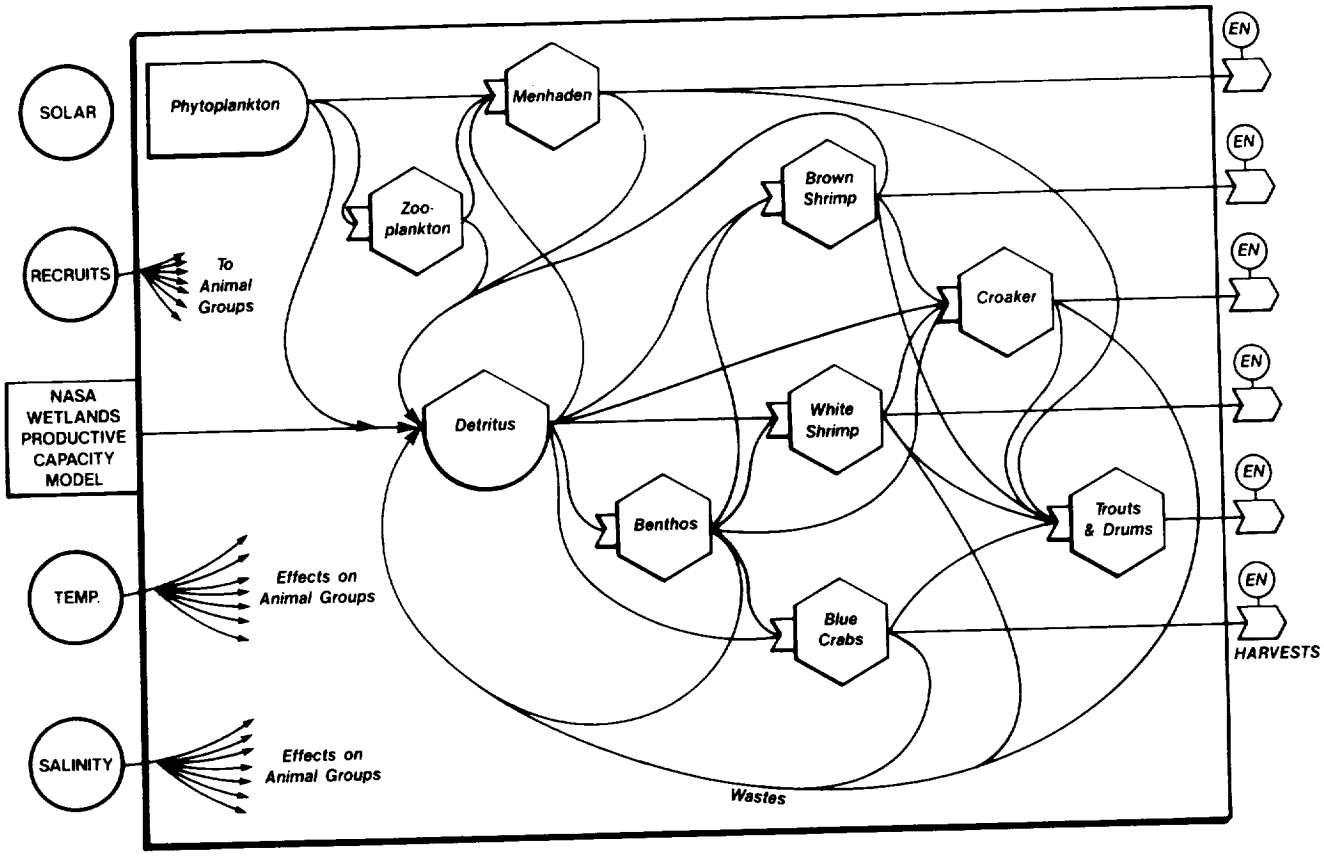


Figure 16. Estuarine Ecosystem Energy Flow Model

The AVHRR data for Florida were processed using ELAS Module CAUSE to determine the utility of AVHRR Channels 1, 2, and 4 to delineate inundated or waterlogged wetlands. Monthly CAUSE-classified AVHRR images of the Florida Everglades were made and compared with hydrology data (precipitation and water depth) to watch the change in inundation boundaries as the Everglades moved from the dry season into the wet season. Since methane is produced only in anaerobic conditions, areal extent estimates of inundated areas, in addition to wetland types, were needed for calculating total methane flux. With these areal extent estimates made from AVHRR, the methane flux and hydrology models were extended from local to regional areas.

An AVHRR surface cover stratification of Gulf of Mexico wetlands was developed as a base line for extending the methane flux model into different wetland ecosystems over large regional areas.

LAND-SEA INTERFACE

During February 1986, NSTL/ERL and the University of Puerto Rico (UPR) initiated a multiyear cooperative research project to improve the understanding of exchange processes between terrestrial and marine ecosystems. The participating members of the UPR community are the Terrestrial and Marine Ecology Divisions of the Center for Energy and Environment Research (CEER) and the Marine Science and Engineering Departments of UPR at Mayaguez. FY86 activities focused on upgrading institutional remote sensing capabilities for studying biogeochemical cycling mechanisms between major components of the environment. Part of these activities included installation of microcomputer-based image processing capabilities at two UPR facilities. These two systems also serve as a geographic information system for spatial data analysis. A larger computer system with increased image analysis capability will be developed in 1987 and shared by

the Geology, Engineering, and Marine Science Departments.

Other activities during FY86 included software development and the collection of surface truth and remotely sensed data. Field missions were conducted in conjunction with an aircraft mission to acquire Thermal Infrared Multispectral Scanner data and aerial photography along the coastlines and over forested areas where environmentally important variables are to be measured. Satellite data that were acquired by the Landsat Multispectral Scanner, the Thematic Mapper, and the Coastal Zone Color Scanner (CZCS) aboard Nimbus-7 are being analyzed in both Puerto Rico and at ERL.

Several investigators from Puerto Rico were in residence at ERL during FY86 for training, collaboration, and research. This was made possible by planning the project in concert with the Summer Faculty Program and the Graduate Study Research Program. One of the major contributions of the Summer Faculty research was to compile several CZCS algorithms to run on the ERL ELAS system. It is now possible to process CZCS data sets to extract quantitative chlorophyll pigment information that relates to global, oceanic primary productivity. Other benefits derived from this effort were various sun-sensor geometry corrections, atmospheric correction techniques based upon inherent data values, and a geo-registration technique based upon modeled orbital parameters. Additional benefits resulting from the development of this software package are Rayleigh and Mie scattering corrections that greatly improve its extendibility, utility, and applicability to other data sets.

SOIL DELINEATION

The research goals of RTOP 67-21-29-01 include developing new remote sensing techniques capable of delineating soils and soil properties within the visible, reflective infrared, and thermal infrared portions of the spectrum. This goal is being addressed through a three-stage approach using spectroradiometer measurements (from a Barnes Model 12-1000 modular multiband radiometer) acquired under controlled laboratory conditions and in the field, and using remotely sensed spacecraft- or aircraft-acquired data from the TM or TIMS for a cross section of U.S. soils exhibiting a variety of physicochemical and environmental conditions.

One aspect of the research this year focused on soil moisture—an environmentally dynamic parameter. Previous research under this project had indicated that a ratio of TM Band 5 to Band 7 provided the best index of soil moisture content of all the ratios investigated, though slopes of the correlation curves changed significantly between soils and moderately within a soil over increasing gravimetric water contents. Comparison of gravimetric water content (percentage) with the TM Wetness Component (Crist and Cicone, 1984) improved the curves somewhat by making the slope of the correlation curves almost constant within a soil, but still not constant between soils with differing properties (Figure 17). This find could prove useful as a means of differentiating soil types through remotely sensed data.

Considering a different approach, the utility of remotely sensed "wetness" to estimate soil moisture status would be enhanced if the differences between soil types could be accounted for and eliminated. By calculating the moisture content as a percent of the potential water content of 100 cm of tension (a value near "field capacity"), the correlation curves take on a much more constant slope both within and between soils, except at saturated levels, for which the slope approaches zero (Figure 18). Further investigation will permit the soil curves to be normalized for dry "wetness" values based on known soil parameters such as organic matter or iron oxide content. For more details refer to Musick and Pelletier (1986a).

Another component of research under the soil delineation project deals with analysis of Thermal Infrared Multispectral Scanner data. A new model was developed for computing the relative differences in emissivity between two TIMS bands (Ochoa, et al., 1986). The significance of this model is that no *a priori* knowledge about the soil temperature or soil emissivity is needed since the model is based completely on data computed from Planck's black body radiation equation. TIMS Bands 2 and 5 were selected to compute delta emissivities because the largest delta emissivities for soil were observed between these two bands, ranging from 0.04 to 0.15. Quartz composition appeared to be primarily responsible for this large contrast; high quartz soils exhibited high delta emissivities and low quartz soils exhibited low delta emissivities (Figure 19). The determination of quartz content and spatial distribution using TIMS-derived delta emissivity data allows many of the remaining soil

attributes to be inferred and general characterizations of the soil to be made. The inclusion of geologic information could further aid geomorphologic studies of this type and will be investigated in the coming year.

In addition to developing techniques for utilizing remotely sensed data to map soils and soil properties, a study was made of the spatial accuracy of digitized soil data bases as cell size increased. As digital soils data become more commonly used in geographic information systems, the aspect of accuracy at a variety of cell sizes is an important concern. While it is well understood that accuracy necessarily declines as cell size increases, the rate at which this decline occurs is dependent upon a number of factors, including the complexity of the mapping units and geographic scale in question. Table 6 illustrates an example of the rapid decrease in accuracy for a number of frequently used cell sizes of a moderately complex soils data set encompassing an area of 25 square kilometers. For field-level research, very small cell sizes will be necessary for the detailed analysis required, while for broad-scale studies the accuracy attainable at larger cells may be acceptable given the tradeoffs of economies of scale.

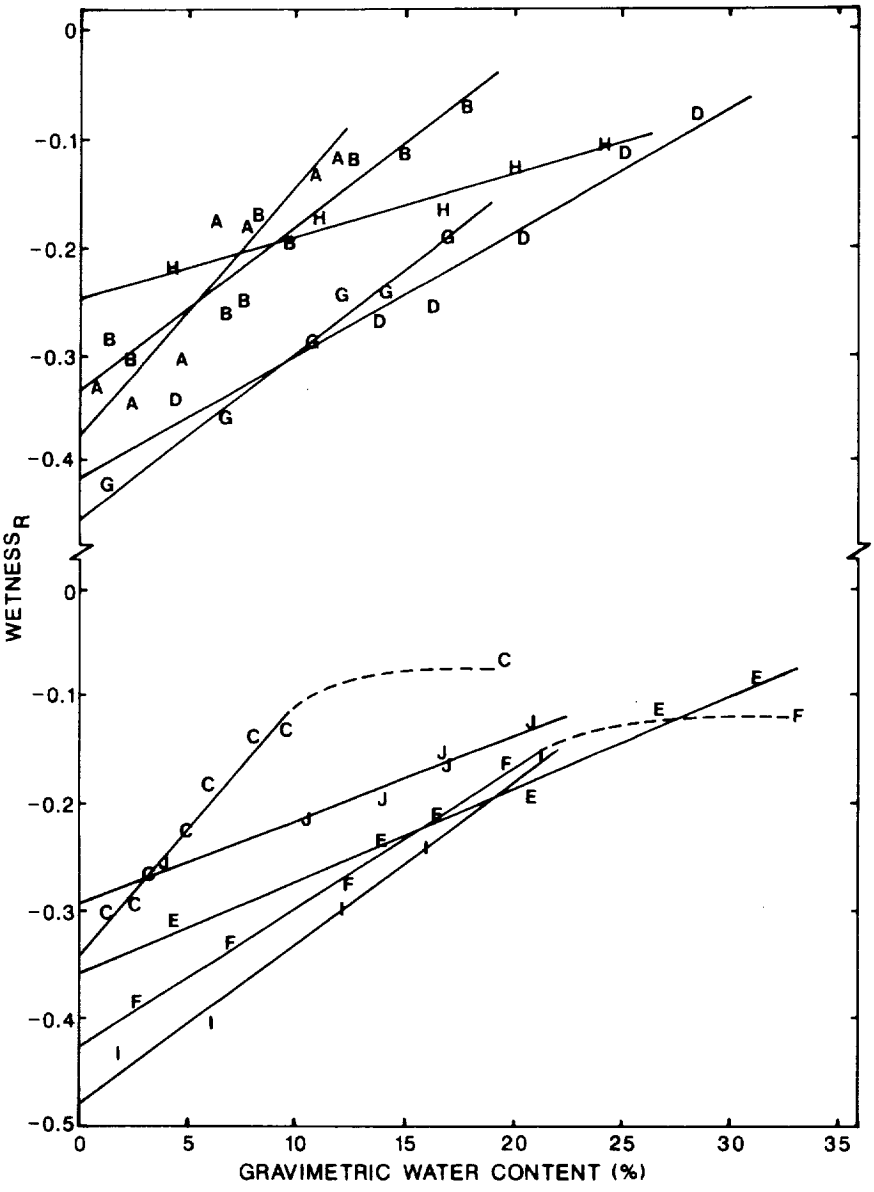


Figure 17. Response of TM Wetness Component Values, as Derived from Barnes Radiometer Data, to Gravimetric Soil Water Content

ARCHEOLOGICAL STUDIES

Costa Rica Archeology

Remote sensing research in Costa Rica is helping to decipher the archeological record of several prehistoric cultures. Ten volcanic eruptions of the Arenal Volcano during the past 3,000 years have left buried ashfalls that have preserved the lifestyles of prehistoric populations. Tropical regions are notorious for rapid decomposition and decay, yet the Arenal region is revealing information concerning the prehistoric relationships of people with their environment, climate, and cultural adaptation. Although an elite graveyard with over 4,000 graves has been discovered, the cities and villages responsible for the burials have not been found. In the NASA remote sensing photography and radar data, however, the lineaments of pathways and roadways leading away from the graveyard are visible. These pathways cannot be seen from ground level. Fieldwork

conducted during 1985-1986 confirmed the existence of these pathways.

These roadways have been traced for several kilometers across the jungle landscape, with over 30 trenches having been excavated to verify their locations. In addition, artifacts have been recovered from certain layers which demonstrate that there were two major roadway systems in use. While the major settlement area has not been discovered, the images suggest its location and a field mission is scheduled for the summer of 1987 to substantiate its location. Evidence from more than 60 sites, supported through carbon-14 dating, has revealed several occupational phases with unique cultural patterns ranging from 2500 B.C. to Spanish conquest.

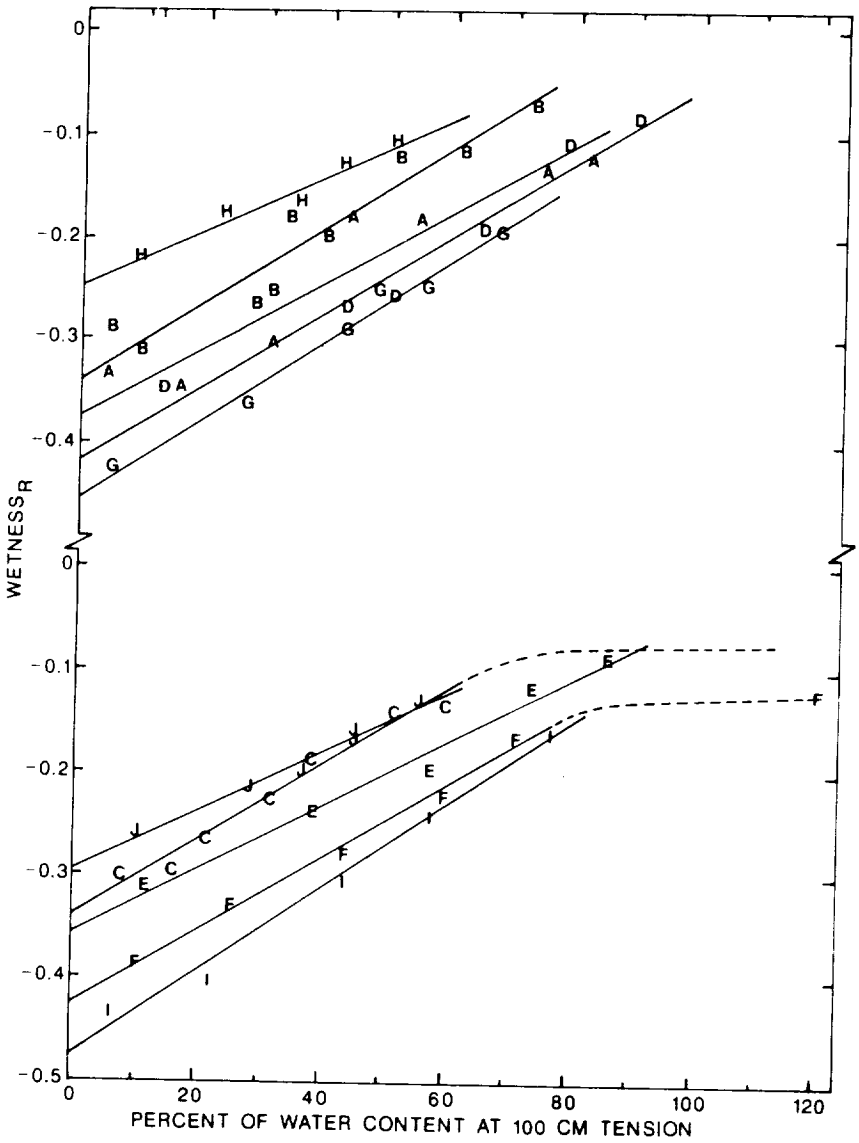


Figure 18. Response of TM Wetness Component Values, as Derived from Barnes Radiometer Data, to Relative Gravimetric Water Content at 100 cm of Tension

A geobased information system has been constructed using Landsat MSS and TM data, lidar data, L-band radar data, color infrared photography, color aerial photography, and ancillary data such as topography, rainfall, known site locations, life zones, and soils. This information will be used to develop algorithms for predictive models which will isolate potential areas for prehistoric settlement patterns. In addition, corridor analysis techniques will be used to assist in understanding the purpose and location of the roadway systems.

The NSTL/ERL effort is part of a cooperative research project between NASA, the National Science Foundation, and the University of Colorado. The ultimate purpose of the project is to demonstrate the cost-effective techniques of remote sensing in detecting archeological sites, development of predictive models, and understanding the relationship of man-land interactions through time. It is felt that this information will contribute inestimably to policies affecting contemporary populations and their subsistence strategies.

Yucatan Archeology

As part of a cooperative agreement between NASA and the National Geographic Society, investigators are using Landsat Thematic Mapper data to locate archeological sites and roadways of the prehistoric Maya in the Yucatan. Advanced filtering techniques have accentuated

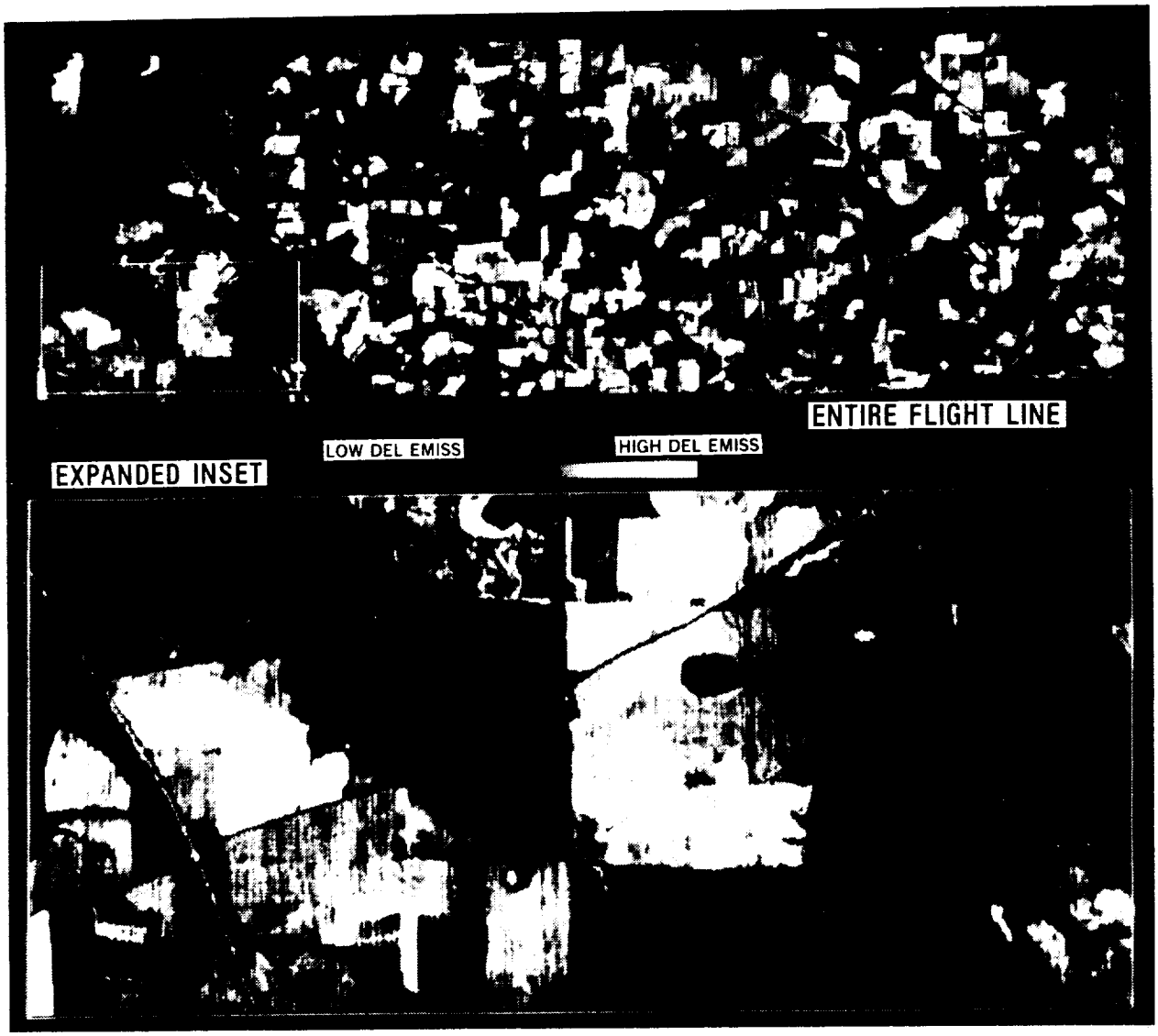


Figure 19. TIMS Image of Delta Emissivity Between Bands 2 and 5

lineaments which have been verified as being "sacbes," which were the elevated straight roadways of the Maya. Mapping the location of the sacbes is expected to reveal new cities as well as an understanding of the relationships and interaction-spheres of prehistoric Maya settlements. In addition, "cenotes," or water wells, are being mapped since there is a direct relationship between water sources and site locations in the Maya area.

Deforestation, urban development, mineral exploration, and agricultural extension are destroying archeological sites at an alarming rate around the world. Through the use of the non-destructive techniques of remote sensing, however, prehistoric sites can be discovered, prioritized, analyzed, and subsequently protected. As a result of ERL's efforts, the application of remote sensing to archeology is being adopted by various universities and professional organizations across the nation, including the University of Colorado, Boston University, the National Science Foundation, and the National Geographic Society.

URBAN MICROCLIMATE STUDY

In conjunction with the U.S. Man and Biosphere (MAB) Program's Urban Ecosystems

Table 6
Cell Size Versus Percent Accuracy for Moderately Complex Soil Data Base

Cell Size (m)	Percent Accuracy
5.0	100.0
10.0	95.5
30.0	78.6
50.0	77.0
63.5	82.0
100.0	62.5
120.0	70.2
200.0	47.0
250.0	40.1
300.0	43.2
400.0	31.0
800.0	21.0

$r = -0.87$
slope $= -0.088$

Directorate, NSTL/ERL has been investigating the relationship between the distribution and material type composition of various surfaces within the urban landscape, and the effect these land covers have on the development of the microclimate which presides over a city. The Salt Lake City, Utah, metropolitan area has been chosen as a study site because of the associated research by the Utah Department of Natural Resources and the U.S. Forest Service which is in progress within the immediate area.

This investigation is designed to measure upwelling longwave energy (reflected or emitted) over an urban surface as a function of discrete land covers, and evaluate how the character of the altered landscape within the city affects longwave energy responses from specific surfaces on a diurnal basis. Intrinsic to this research will be the use of data from the Thermal Infrared Multispectral Scanner, acquired daily at times of minimum and maximum solar irradiance, to derive a quantitative estimate of the flux dynamics of radiation reflected or emitted by the urban surface. Additionally, *in situ* ground level radiation thermometer and local meteorological data, obtained coincidentally with the acquisition of the remotely sensed thermal data, will be used to augment and support the measurement of longwave energy reflected and emitted from the city landscape. As a function of this overall objective, the proposed research is expected to provide a first order estimate of:

- The state of longwave energy processes extant over disturbed or altered surfaces, such as those present within an urban area (i.e., the relationship of reflected and emitted energy from specific materials or land covers).
- The fluxes in energy dynamics which occur for these surfaces or land covers over a diurnal period (i.e., for a one- or two-night/day observation period).
- The rate or magnitude of change in upwelling longwave energy associated with discrete surfaces and land covers associated with the city landscape.

In support of this research effort, TIMS data were collected twice daily over Salt Lake City between August 12 and August 15, 1985. These data were acquired at approximately 5:00 a.m. and 1:30 p.m. MDT for each of the four days the sensor was flown, and coincide with times of minimum surface temperature (i.e., early morning) and solar noon, or maximum solar irradiance (i.e., about 1:30 p.m. local time). The collection of thermal infrared data at times of minimum and maximum solar irradiance provided reference points for the comparative measurement of diurnal flux dynamics which occur for upwelling longwave energy reflected or emitted from the surface within a summer climatic regime. For this particular study, one night/day acquisition period provided the data required to measure longwave flux dynamics for specific urban surfaces.

TIMS data were obtained at low altitude (5-meter spatial resolution) over the Salt Lake City study site to facilitate the measurement of longwave radiation from discrete surface material types across the heterogeneous urban landscape. The 5-meter resolution of the thermal infrared data acquired for the study area provides detailed spatial information over the city surface, a factor which has been remiss in other urban energy balance studies. The six-channel thermal design of the sensor also permits the measurement of longwave energy in much narrower bandwidths than have been utilized in past investigations that have employed remotely sensed thermal scanners for analysis of the city landscape.

Four particular locations, with a wide diversity of land cover types, are being examined using the TIMS data: (1) a portion of the Salt Lake City central business district (CBD); (2) an urban park near the CBD with large trees and heavy canopy closure, along with portions of an adjacent older residential area; (3) a suburban

park and golf course with few trees and an abundance of grass, located near the Wasatch Mountains toward the southern end of the TIMS flight line; and (4) a newer suburban residential area at the southern end of the TIMS flight path with vegetation and surfaces that represent a composite of the surface types found in the other three sites. *In situ* ground data acquired with hand-held precision radiation thermometers were obtained for these areas at the same times as the aircraft overflights. The ground level data are being used to check the veracity of the TIMS data and to provide additional information on surface energy characteristics which will be used to evaluate upwelling longwave energy fluxes from different urban material types. Additionally, atmospheric sounding balloon (i.e., radiosonde) data were obtained during the TIMS overflights to support the appropriate modeling of energy responses as affected by atmospheric anomalies, such as pollutants and water vapor, which have a deleterious influence on thermal infrared remotely sensed data.

This research is expected to yield significant insight into how the altered landscape within urban areas influences the development of the urban climate at both the microscale and mesoscale. Moreover, examining city surface-to-atmosphere relationships will provide a better understanding of the role of the urban landscape within the urban ecosystem.

GEOLOGICAL REMOTE SENSING RESEARCH

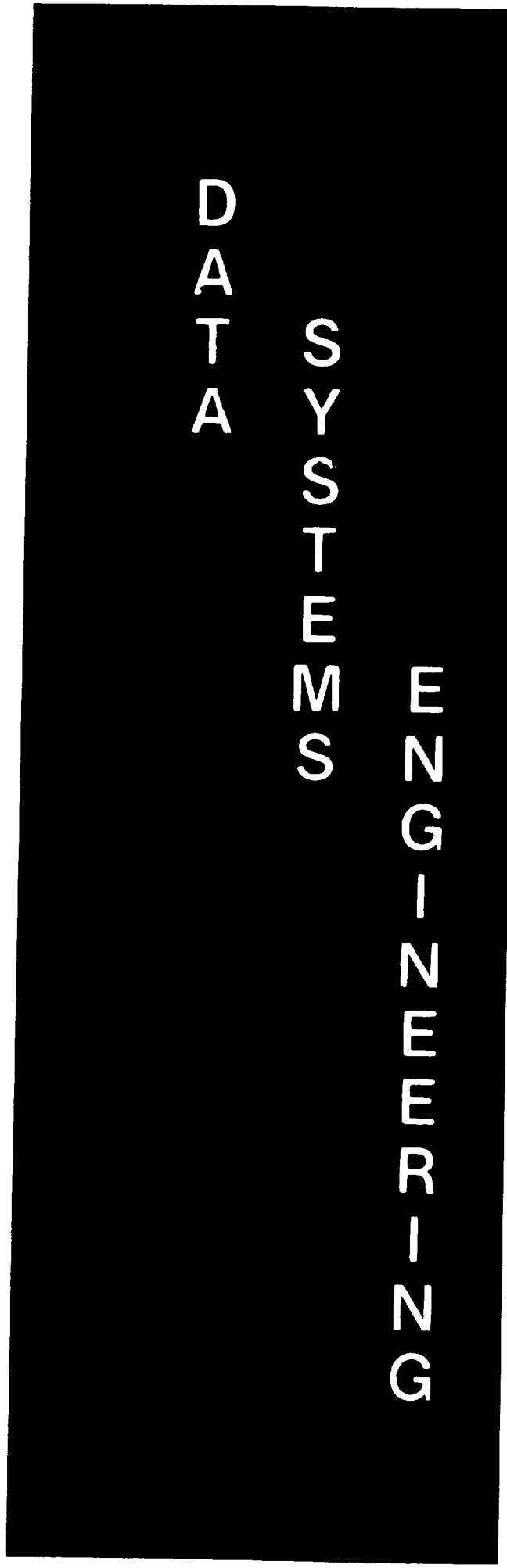
The objective of this continuing project is to determine the utility of integrated TMS and TIMS data to discriminate and map several basic geologic phenomena. The effort is nearing conclusion with the preparation of journal articles addressing the wide range of results from analysis of the Lordsburg, New Mexico, data set. Topics include: (1) the use of TIMS, uncorrected for atmosphere, to remotely measure the amount of silica in a rock; (2) the practical problems of applying atmospheric corrections to TIMS data, and (3) a basic map of the area produced from the imagery with the associated chemical analyses.

Partially as a result of this project, a practical capability now exists to radiometrically correct TIMS data for atmospheric effects. The software which does the computations generates floating point numbers for each pixel, one value for each channel of data. These values are the energies within the particular wavelengths emitted by the material on the ground. Corrections include allowance for the changing path length with scan angle, the atmosphere's transmissivity and emissions by wavelength, and the scanner's responsiveness by wavelength.

The effort to quantitatively measure silica demonstrated the expected strong correlation of the rock's silica content with between-channel variation in the TIMS data. However, it also showed that the current scanner does not have sufficient sensitivity and/or signal-to-noise to permit more than rather broad estimates of a rock unit's silicon dioxide content. Differences of more than 10 weight-percent silica are quite separable; differences of less than 5 weight-percent are hidden within the noise. Visually, finer discriminations over broad areas are possible, but quantitative analysis is limited for targets smaller than 20 to 40 pixels.

DATA SYSTEMS ENGINEERING

- Earth Resources Laboratory Applications Software
  - Additions to ELAS Software
  - Automated Scanning Digitizer Capability
- Global Resources Information Database
- Automated Information Management Program
  - Major Objectives
  - Management Accounting and Statusing System (MASS)
  - Project Example—NSTL AIM Training Project
  - NASA Guidelines and Considerations
  - Software Applications
  - Computer Hardware
- FNOC Satellite Processing Center Upgrade
- Space Station Data Management System Testbed Support



DATA SYSTEMS ENGINEERING

EARTH RESOURCES LABORATORY APPLICATIONS SOFTWARE

The Earth Resources Laboratory Applications Software (ELAS) was developed by NSTL/ERL personnel for processing and analyzing digital data from remote sensors (such as multispectral scanners) in conjunction with digitized information concerning topography, soil types, rainfall, and other ancillary data. ELAS includes an operating subsystem that functions under the computer's standard operating system and uses a common data file format and common system interface routines. This configuration increases portability of the software to unlike computer systems and facilitates the addition of new program modules. The production version of ELAS on the ERL Concurrent (formerly Perkin-Elmer) computer system contains approximately 300 separate executable programs designed to provide a wide variety of tools to support processing and analysis of remotely sensed data for either scientific research or operational applications.

Currently, ELAS is used in 36 states, Puerto Rico, Canada, Mexico, Switzerland, and Kenya. ELAS has been installed on most popular minicomputers, and is used by universities, State and Federal agencies, and the private sector.

In 1983 the NASA/NSTL Earth Resources Laboratory was instrumental in the formation of the ELAS Users Group. The purpose of this group is to provide a coordinated means for disseminating information concerning the ELAS package. The users group includes those who have already implemented ELAS on their computer systems as well as those who plan to implement the software at a future date. Members of the ELAS Users Group may have all or a portion of ELAS functioning on their machines. A meeting of the Users Group is held yearly to facilitate information flow. The annual meeting is held at NSTL because ERL authored the software and documentation, is still actively enhancing the package, and remains the foremost location of concentrated user expertise. In addition, ERL has facilities for limited training sessions during the conference. This meeting provides an excellent forum for the user community to exchange information concerning newly developed and/or upgraded application modules, documentation needs and improvements, software problems/solutions, and innovative applications.

The current mailing list for the ELAS Newsletter consists of 150 interested parties. Users continue to rely heavily on ERL for continued support in the development, maintenance, and improvement of the ELAS package.

Additions to ELAS Software

Numerous capabilities have been added to ELAS during FY86 to increase flexibility and analytical power of the software package. A significant number of selected core modules (80) have been modified to accommodate data elements exceeding eight bits in length. These modifications are part of an effort to upgrade ELAS to routinely handle multibyte elements, both integer and floating point. Also of interest is the release of the new external statistics file (STF), which enhances the capacity and traceability of statistics processing.

The following are new capabilities:

- CEKS—Classifies contour line type.
- CLPIPE—Performs user-controlled parallelepiped classification.
- FIND—Finds and describes closed complexes composed of specified classes.
- HISD—Adjusts hue intensity and saturation.
- INFO—Tabulates frequency of occurrence information.
- LVIN—Finds entities of PGF with vertices within user-defined circle.
- RFDMA—Reformats DMA digital terrain elevation data.
- RFEKDA—Reformats Eikonix scanning digitizer data.
- RFERDAS—Reformats an ERDAS-written tape.
- SPRB—Changes 6-bit color table (64 colors) to an 8-bit table (256 colors).
- TRADE—Computes atmospheric correction and thermal radiant energy for TIMS data.
- TREN—Fits a curve in three dimensions (a surface) to an ELAS 8- or 16-bit file.

- VEKS—Corrects vignetting phenomenon in an ELAS data file.

- ZEKS—Assigns elevation data values to contour lines.

Also under development is a Fourier analysis capability within ELAS and the conversion of the CAUSE/ICARUS software for Advanced Very High Resolution Radiometer (AVHRR) processing.

Automated Scanning Digitizer Capability

NSTL/ERL operates an Eikonix 78/99 scanning digitizer that provides the following:

- The ability to scan an object with an overall spatial resolution of 2048 elements by 2048 scan lines.

- Optional pixel resolutions of 8 bits (0–255 dynamic range window) or 12 bits (0–4095 dynamic range window).

- Black and white scanning utilizing a clear filter or color scanning using red, green, and blue filters.

- The capability to digitize maps, photographs, and documents using incandescent light sources, while transparent objects such as film negatives, acetate maps, and contour-based maps can be scanned with a luminescent light source.

- The ability to digitize black and white photographs in less than 3 minutes and color products in less than 8 minutes.

Additionally, ELAS has provisions to perform the following functional tasks on digitized images: statistical regression, correlation, and canonical analysis; data classification; boundary detection; georeferencing; polygon declaration and manipulation; circle declaration and manipulation; data destriping; multitemporal registration; principal components analysis; three-dimensional perspective modeling; stepwise multiple regression; fast-Fourier analysis; digital filtering; logical pattern shifting; radiance value shifting; data cell to selected cell size resampling; context analysis; stereo analysis; and digital geometry.

GLOBAL RESOURCES INFORMATION DATABASE

NASA and the United Nations Environment Programme (UNEP) entered into an agreement which establishes the basis for a cooperative project to develop methodologies for the processing, storage, retrieval, and analysis of data in support of the Global Environmental Monitoring System (GEMS). Under the terms of the agreement, NSTL/ERL and the GEMS Program Activity Center (PAC) are working together to develop approaches and methodologies required for the design and implementation of a Global Resources Information Database (GRID).

Practical applications in the use of the data base are being promoted by GEMS/GRID to accelerate distribution of information useful for national and global planning by governments and various institutions. These applications are encouraging correlation of remote sensing data with ground-observed data as a regular part of the GEMS/GRID effort to improve quality and reliability of the data.

The first GEMS/GRID node was installed by NSTL/ERL in Nairobi, Kenya, in May 1985 and was demonstrated to the United Nations Governing Assembly. The second GEMS/GRID node was installed by NSTL/ERL in Geneva, Switzerland, and was officially commissioned by Dr. Mostafa Tolba, Executive Director of the United Nations Environment Programme, in late September 1985.

Distribution of data through a communications network connecting the GRID nodes is currently being addressed. NSTL/ERL has implemented and demonstrated a telecommunication link between Concurrent (Perkin-Elmer) computers at NSTL and in Geneva, Switzerland. An ELAS scene file was transmitted to Geneva over voice-grade telephone lines using 1200-baud synchronous modems. Also, telecommunication was demonstrated between IBM PC/AT's at NSTL and Nairobi, Kenya. Earth Resources Data Analysis System (ERDAS) data files were transmitted from NSTL to Nairobi and from Nairobi to NSTL over voice-grade telephone lines using 2400-baud modems.

NSTL/ERL has also provided a data processor/analyst and computer programmer full time in Geneva to support the GRID effort. ERL will continue to support GRID in the areas of programming, data processing and analysis, communications, and computer system maintenance through the end of the 2-year pilot program in December 1987.

AUTOMATED INFORMATION MANAGEMENT PROGRAM

Major Objectives

The major objectives of the NSTL Automated Information Management (AIM) program include providing state-of-the-art integrated automation tools to managers, administrative personnel, scientists, and engineers, thereby increasing productivity, efficiency, and work performance. Another objective is to effectively introduce AIM tools/systems through the support of AIM-related Automated Data Processing (ADP) training. On-going activities include implementation of personal computing, telecommunications, and networking capabilities to support Space Station, program management, and R&D activities. To meet these objectives, several programs and plans were either continued or initiated in FY86.

The NSTL Automated Information Management Strategic Plan to support the AIM Program was continued during FY86. During the first 2 years of this 5-year plan, peripherals for the IBM 4341 have been significantly upgraded to support administrative programs. The VAX 11/780 has been upgraded to 12 MB of memory, four additional unibus controllers, and another unibus adapter to support a mixture of administrative, scientific, and program management functions. A comprehensive Office Automation (OA) plan is in the second year of implementation and will provide end users with microprocessor-based, multifunction workstations. Acquisitions in FY86 cover procurement of both low performance (8-bit) and high performance (16-bit) workstations. NSTL applications supported by Office Automation are depicted in Figure 20. Host computers/networks accessible from NSTL OA peripherals are shown in Table 7.

The Ada Programming Support Environment (APSE) with the Ada compiler was acquired in FY86. The APSE provides the foundation for developing an understanding of the capabilities of this new language and support environment. Implementation of the Ada programming language is scheduled for controlled testing in early FY87.

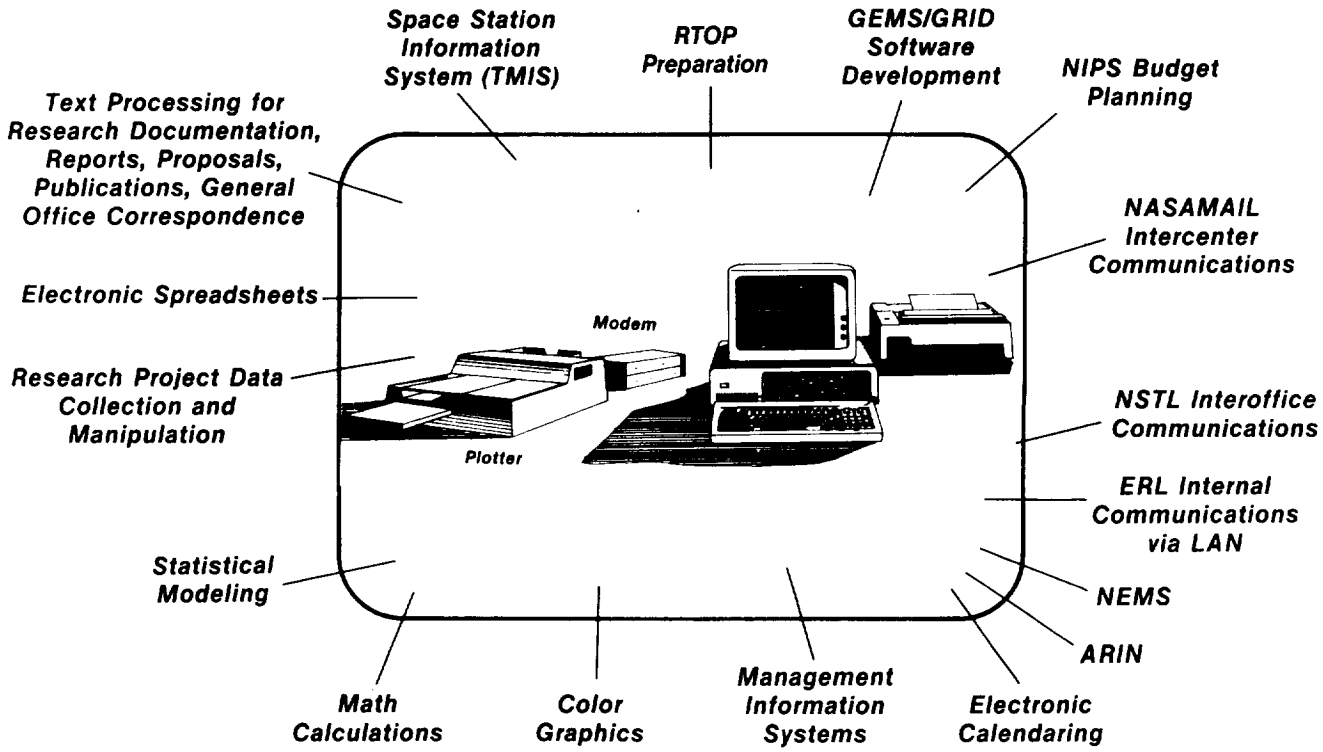


Figure 20. NSTL Applications Supported by Office Automation

Table 7
Host Computers/Networks Accessible from NSTL Office Automation Peripherals

- Concurrent (Perkin-Elmer) R&D Systems
- IBM 4341—VAX 11/780 Host—Node Network
- Program Support Communications Network (PSCN)
- Headquarters IBM and VAX Mainframes

Terminals	Personal Computers	Word Processors
• VT 100/125/220	• IBM PC	• DECmates I, II, III
• P/E 550	• PC/XT	• IBM Displaywriter
• Displayphone	• PC/AT	
• Televideo 925	• 3270 PC	
• IBM 3180	• Tandy 4	

Management Accounting and Statusing System (MASS)

MASS is a modern and efficient software system being developed to handle NSTL's institutional mission requirements on the IBM 4341 computer system. This system will provide computerized management information in the following functional areas designated as software releases:

- Release 1—NASA Finance Application.
- Release 2—Facilities Operating Support/Technical Support Contractor Finance Application.
- Release 3—Inventory Control System.
- Release 4—Tracking and Statusing System.

Each release is operationally independent and will support identified user requirements as each release is placed into production. The rewrite of Release 1 of this software to run on the IBM 4341 was near completion at the end of FY86. The effort on Releases 2, 3, and 4 was continued in FY86.

Project Example—NSTL AIM Training Project

The NSTL AIM training project was established in FY86. This effort has resulted in the development and implementation of a training program that includes courses such as Microcomputer Basics, Graphics, Communications, and Lotus 1-2-3 spreadsheets.

The training center provides support to the user community in solving software problems encountered either during or after software installation. A "help desk" responds to requests for assistance.

A monthly newsletter, "From the Bit Desk," informs the user community of AIM-related activities, including scheduled courses, seminars, and the availability of training cassettes, materials, and publications.

NASA Guidelines and Considerations

The first agency system installed at NSTL was the NASA Equipment Management System (NEMS). This system became operational in June 1986 and provides capability for daily updates to a central data base at the NASA Headquarters Scientific and Technical Information Facility (STIF). The Aerospace Research Information Network (ARIN) was also implemented at NSTL during FY86.

Software Applications

VAX 11/780 System

The VAX 11/780 supports approximately 90 information systems. A number of users are supported by VAX-hosted office automation software. An online Configuration Control System is also used for single-screen software status tracking and documentation.

IBM 4341 System

The IBM 4341 system supports NSTL management, institutional, and administrative activities, including the MASS being developed with ADABAS/Natural software.

The 4341 will also support the NEMS, Telephone Information Management System (TIMS), and other applications software to be developed over the next 5 years.

Microprocessor Software

The following software application and operating systems have been implemented on PC-based workstations: MS/DOS operating system, dBase III relational DBMS, Lotus 1-2-3 spreadsheet, Crosstalk XVI communications, Prokey keyboard automation, Sideways horizontal printing, Sidekick calculator and utility tool, Wordstar 2000 word processing, and Microsoft Mouse data input.

In addition, limited use and evaluation of the following software packages are ongoing: PC Network networking software; Symphony integrated spreadsheet, DBMS, etc.; Topview windowing; Energraphics graphics plotting; Languages Fortran, COBOL, Pascal, C; and Smarterm 100 terminal mode to VAX.

Other Systems Support

NSTL relies on the Slidell Computer Complex for micrographics support to the NASA Finance Office and for batch processing of production jobs associated with facilities support information systems, maintenance management, real property management, gas cylinder inventory, catalog of NSTL stock items, transaction log for catalog items, and the Defense Logistics Supply Center catalog.

The existing NASAMAIL service at NSTL provides dialup capability to Telemail via the NASA Packet Switching System. NSTL users transmit correspondence, reports, proposals, announcements, and messages through NASAMAIL in support of program management and administrative activities.

Computer Hardware

Host System Architecture

The VAX 11/780 hardware configuration consists of 12 MB main memory, 2 GB disk storage, 2 tape drives, 4 high-speed printers, and 110 other peripheral devices. Also, a Northern Telecom Data 100 is linked to the PSCS via a direct cable and a null modem, utilizing an interface with IBM 2780/3780 protocol.

The IBM 4341 peripherals include 2 disk drives (5 GB storage), a disk controller, 2 tape drives, a tape controller, a 2000-LPM printer, a communications controller configured with 6 line interface couplers, 4 terminal controllers, an ASCII device controller, 32 display stations, 12 printers, and data communications equipment. This system will have the capability initially to support a minimum of 75 online users, with expansion capability to support between 200 and 250 online users.

The IBM/VAX host/node configuration (Figure 21) is sized for present and near-term processing requirements. FY87 plans for the 4341 CPU include memory upgrade from 8 MB to 12 MB and upgrade from the Group 2 to the Group 12 CPU. There are also plans to add controllers and terminals based on user requirements.

Microprocessor-Distributed Systems

Many applications that presently reside on the mainframe systems can be handled more effectively and efficiently on a multipurpose microprocessor. Applications shared among different offices will require PCs interconnected by a local area network. Currently, NSTL has 75 PC workstations to support a staff of 1,100 individuals. An additional 78 PCs will be procured in FY87.

ITS and TIMS

The new NSTL digital, private, automated branch exchange (DPABX) telephone system, referred to as the Installation Telecommunication System (ITS), is on schedule and is targeted for cutover on December 12, 1986. The ITS will provide integrated voice and data communications capabilities to support installation requirements for the next 10 years. Asynchronous and synchronous protocols at speeds ranging from 50 to 57.6K bits per second can be supported. Other capabilities include modem pooling for offsite links, local area networking, format and protocol conversions, and IBM 327x capabilities. To support the implementation, operation, and management of the ITS, the Telecommunications Information Management System was initiated. The application software to support TIMS via the IBM 4341 is under development by the NSTL Technical Support Contractor.

PSCN

The base gateway configuration for the NSTL Program Support Communications Network has been implemented. The gateway currently supports eight data lines for the NASA Packet Switching System (NPSS) and several switched medium-speed circuits. NSTL data requirements for the PSCN will also cover a range of

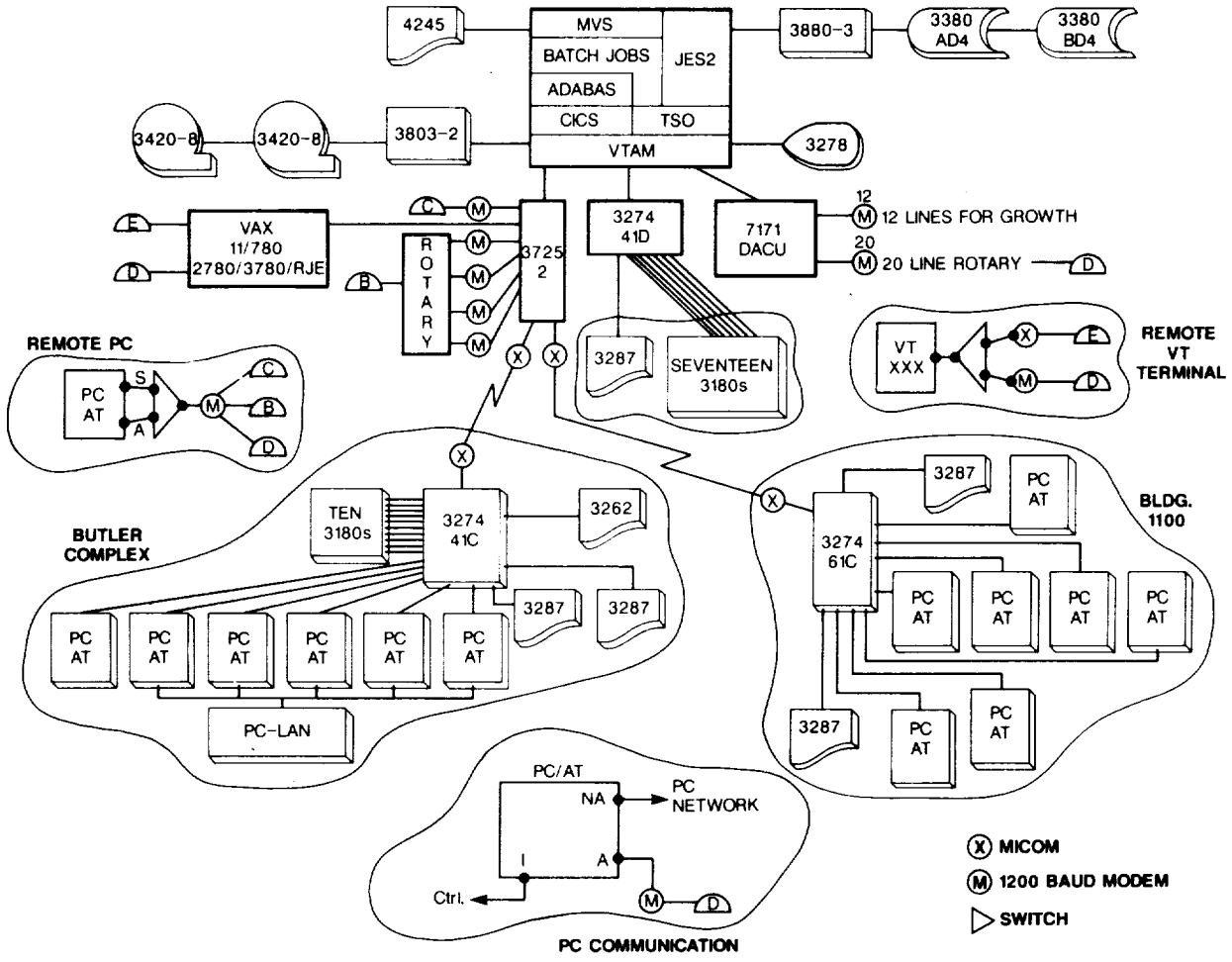


Figure 21. NSTL IBM 4341-VAX 11/780 Host-Node Network Configuration

low- and high-speed packet and circuit switching lines for supporting the Space Station Data Management System Payload Simulator, Pilot Land Data System, ERL Image Analysis, United Nations Environment Programme, ARIN, NEMS, Procurement Management Technology Program, NSTL administrative host computer file transfer, and NASAMAIL.

FNOC SATELLITE PROCESSING CENTER UPGRADE

NASA/NSTL is continuing the design, procurement, development, installation, and test of a Satellite Processing Center (SPC) for the Navy's Fleet Numerical Oceanography Center (FNOC) located in Monterey, California.

The SPC is being designed to meet the Navy's satellite data processing requirements well into the 1990s. It consists of a federated system of state-of-the-art super minicomputers, completely software controllable pulse code modulated (PCM) subsystems for ingesting the satellite data streams, and the latest in color graphic interactive analysis workstations. This computer/hardware system is being designed to receive, process, and archive satellite data from the DMSP, TIROS, and GOES series of satellites in which the atmospheric and oceanic data products will be employed for fleet operations, antisubmarine warfare, and research and development activities. The effort is scheduled for completion in September 1987.

Specifically, the status of the program is as follows:

- Overall system architecture design was complete in December 1984.
- The three major subsystems—computer subsystem, PCM subsystem, and interactive graphics workstation—have been procured and integrated at NSTL.

- Procurement of the graphics terminal workstation has been completed and it is presently being integrated into the computer subsystem.

- Procurement of a subsystem to interface the SPC with the existing Control Data Corporation (CDC) Cyber computers (so that reduced environmental/meteorological satellite data may be transferred to the Cyber computers and then to the Fleet) is in progress.

- Procurement of the camera subsystem will be initiated in the near future.

- The monitor and control software for managing the entire computer hardware environment has been finalized.

- The application software for reducing the DMSP, TIROS, and GOES raw satellite data is being written.

SPACE STATION DATA MANAGEMENT SYSTEM TESTBED SUPPORT

During FY86, NSTL/ERL supported the Johnson Space Center (JSC), Goddard Space Flight Center (GSFC), and Marshall Space Flight Center (MSFC) Space Station Data Management System (DMS) testbed efforts by developing a payload simulator software package. The initial simulator is rather elementary and generic in nature but will evolve in complexity and in phases as Space Station subsystems and their requirements for payload interactions become better defined. In addition to the payload simulator itself, the software package requires two other main components: a workstation emulator and the Space Station DMS testbed emulator. In order to satisfy all users, the simulator has the capability of running as a standalone package or in a combination configuration.

To ensure portability of the software package and to satisfy a Space Station Level B Program Office directive, the payload simulator software was developed in the Ada program language. An entire Ada Program Development System (APDS) was procured. The APDS consists of a Data General MV/4000 and MV/2000 DC computer system, fully integrated with all support hardware, Ada compiler, and Ada programming support software, and linked by an Ethernet Communications network (Figure 22). The MV/4000 was installed in February and the MV/2000 DC arrived in June. NSTL/ERL Space Station personnel received a total of 11 man-weeks of Ada training.

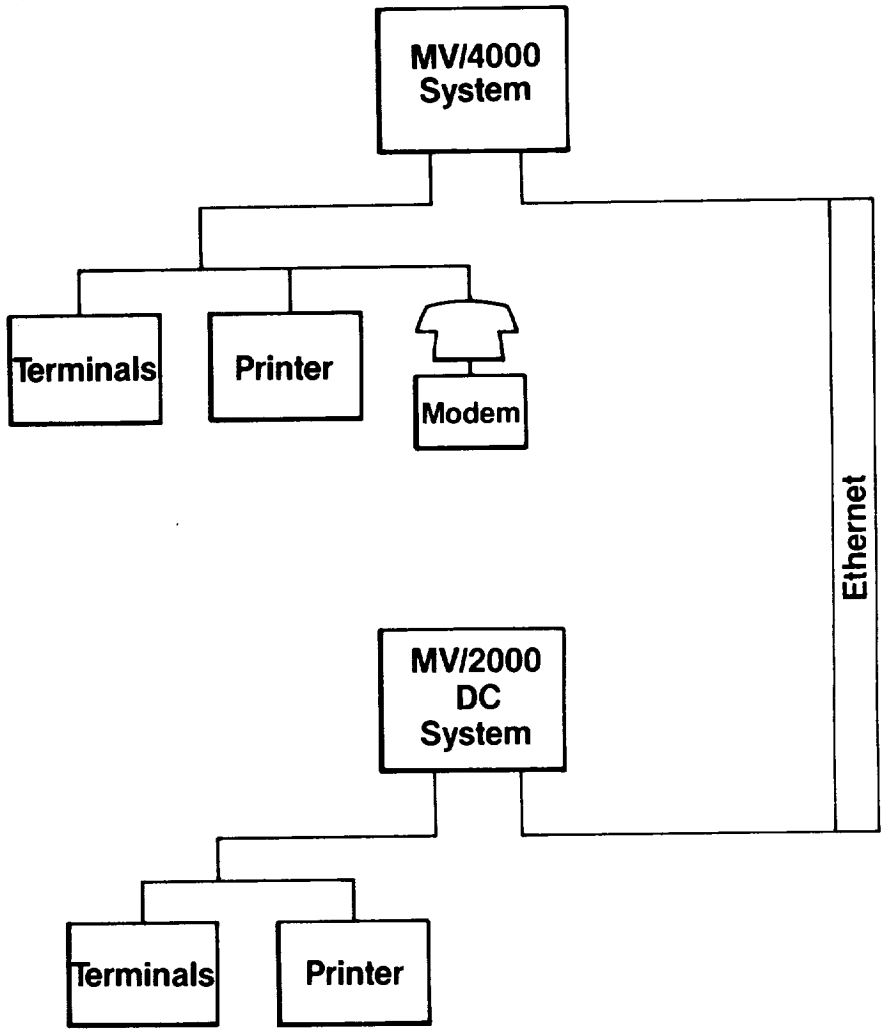


Figure 22. NSTL Hardware Configuration for Payload Simulator Development

Since the payload simulator software package is being developed in Ada, each host hardware environment must be capable of housing an Ada compiler and an Ada support environment. These environments differ at each participating user facility for Phase II and Phase III operations (as defined in the Space Station DMS Advanced Development Project Plan, Appendix B). The primary target for the NSTL payload simulator is the DMS testbed at JSC. Figure 23 depicts the payload simulator interface with this testbed during Phase II configuration. The payload simulator will eventually reside on a Data General MV/8000 and will interface with an integrated fiber-optic ring network of Apollo DSP80 computers. This network will provide communication services for the various subsystem computers in the testbed. A preliminary version of the simulator was installed on an Avionics Systems Division (ASD) VAX 11/785 at JSC in March 1986. The first official release was installed on this system in August. As soon as the MV/8000 becomes operational, the simulator will also be installed on this target machine. At GSFC, the simulator was installed in September on a VAX 11/785-8600 system and runs as a standalone package during Phase II. For Phase III operations, plans call for the NSTL payload simulator to reside on the MV/8000 at JSC and the VAX 11/785-8600 at GSFC. The payload simulator will interface with the DMS testbed via a Customer Interface Adapter and a GSFC-developed star network and gateway (Figure 24).

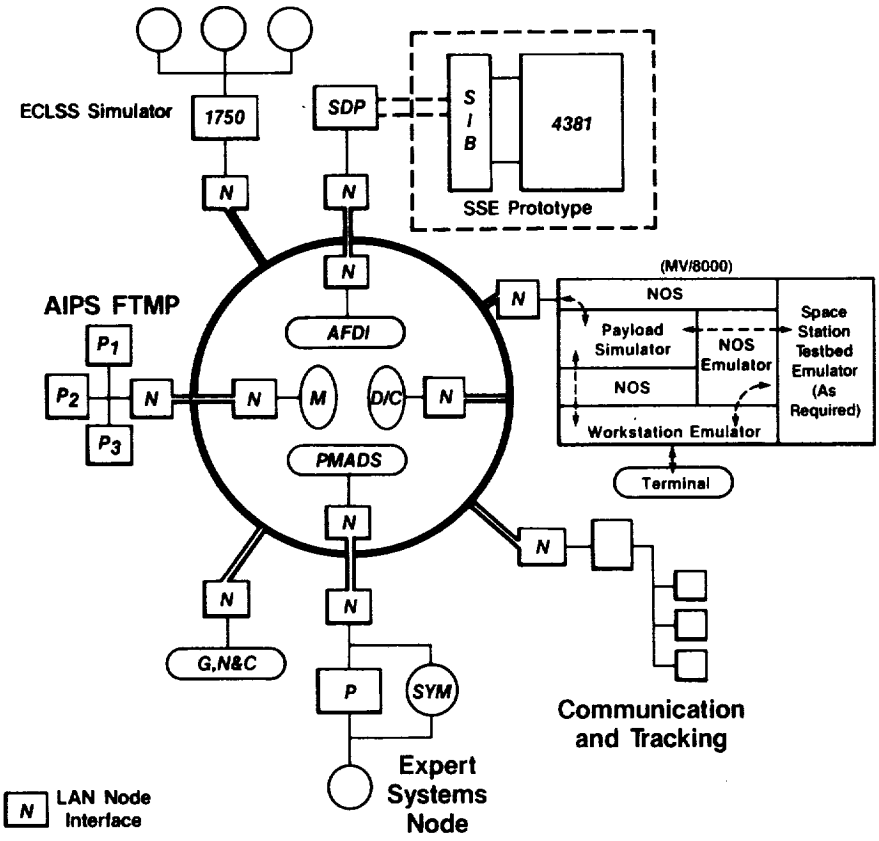


Figure 23. Payload Simulator Interface Phase II Configuration at JSC

The following payload simulator documentation was prepared in FY86: Requirements Document, Detailed Design Document, Payload Simulator User's Guide, NSTL Ada Coding Standards, and Ada Lessons Learned.

An additional aspect in the development of the payload simulator has been to evaluate Ada as a programming language. Ada provides many advanced programming features that should facilitate the development and maintenance of large-scale software systems. NSTL's experience with Ada has been very positive. Over 5,000 lines of code have been written thus far. The design methodology was developed in such a way as to avoid system dependencies, since the payload simulator will run on many different systems. In addition to running on the Data General and VAX machines, the payload simulator has been installed and run on an Intellimac under UNIX. NSTL's experience is that, as advertised, Ada is fairly portable. The Ada Lessons Learned document discusses mostly system dependencies and compiler bugs that have been encountered. It will be updated periodically as more experience is gained.

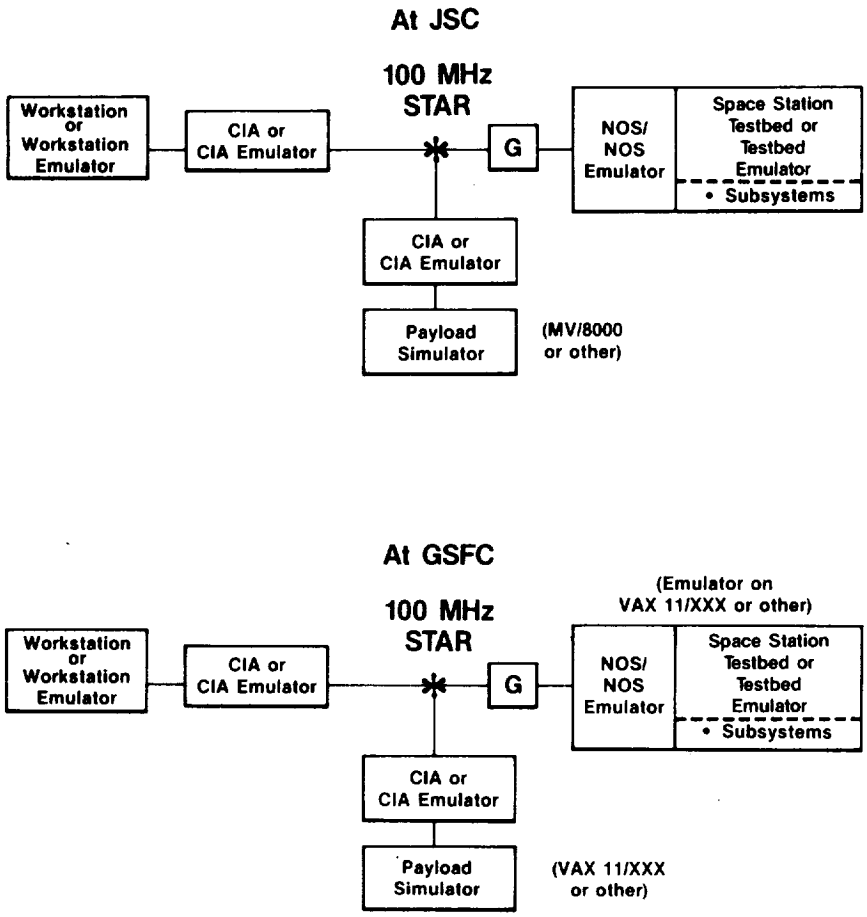


Figure 24. Payload Simulator Interface Phase III Configurations

TECHNOLOGY DEVELOPMENT AND UTILIZATION PROGRAMS

- Technology Development
  - GH_2 Boil-Off Recovery
  - GH_2 Personal Detector
  - Gas Analysis Standards
  - Analysis of Volatile Hydrocarbons
  - Master Control Panel Lighting System
- Technology Utilization
  - Mississippi Technology Transfer Office
  - Environmental Systems
    - Foliage Plants for Removing Indoor Air Pollutants
    - Bioregeneration of Activated Carbon
    - Biological Cleanup of a Hazardous Waste Site
  - Magnetic Resonance Imaging

TECHNOLOGY DEVELOPMENT and UTILIZATION PROGRAMS

TECHNOLOGY DEVELOPMENT AND UTILIZATION PROGRAMS

TECHNOLOGY DEVELOPMENT

Annually, the NSTL Installation Operations Office leads a joint NASA-contractor effort to identify new R&D technology initiatives that support the Center's present and future missions. Candidate projects evolve from innovative ideas developed in employee participation "brainstorming" sessions that are directed toward NSTL-focused areas of Test Technology and Management, Data Management and Acquisition, Environmental Technology, Remote Sensing Technology, and Applied Technology. These projects are categorized by major program areas and then prioritized by the engineering and scientific discipline participants. The highest priority projects are then screened by NASA project managers and incorporated into the appropriate program office submissions. Following are the more significant projects that were initiated or continued during the second year of this creative program.

GH_2 Boil-Off Recovery

An economic trade-off analysis and technological evaluation of hydrogen boil-off recovery and utilization options were conducted. NSTL is one of NASA's largest consumers of hydrogen, both gaseous (GH_2) and liquid (LH_2). Each year approximately three million pounds of hydrogen are lost at NSTL to boil-off from LH_2 barges, pressure vessels, and tanks. This figure is based upon an average of 50,000 pounds of hydrogen lost per Space Shuttle Main Engine (SSME) test firing (boil-off, transfer loss, engine chilldown, etc.). The hydrogen boil-off gas is directed to seven flare stacks throughout the NSTL site and burned. Phase I of the study, completed in FY85, concentrated on identification of recovery techniques and development of new use techniques. Phase II of the study was conducted during FY86 and focused on economic trade-off analysis and evaluation of the recovery and utilization techniques identified in the Phase I study. The results of these two studies will provide the technological basis for decision making during FY87 on potential NSTL facilities for recovery and use of hydrogen boil-off. The information gained from these studies will be disseminated to other NASA Centers and Department of Defense installations.

GH_2 Personal Detector

During the operational testing and standby conditions of the SSME at NSTL, explosive hydrogen gas may escape to the work environment and create potentially hazardous conditions for personnel. Despite the documented procedures for processing and handling these gases, hazardous conditions can still occur during normal purge operations as a result of a mechanical failure or other potential conditions. This technology development objective was to determine the availability of a personal, continuously monitoring GH_2 detector small enough to be issued to all operational test personnel. The requirements for a personal GH_2 detector are quite stringent: continuously monitor GH_2 in an oxygen-depleted environment and in the presence of nitrogen and helium; provide a quick-response indication of GH_2 well below the explosive limit; and be small enough to be attached to a worker's clothing and pose no encumbrance to work activities. Three commercially available GH_2 prototype detectors that showed promise in initial screening were evaluated during FY86. However, none tested satisfactory in their present state. R&D on a new hydrogen detection concept will continue during FY87.

Gas Analysis Standards

NSTL requires a number of pure gases for instrument calibration in support of the SSME test program, but determination of trace contaminants in these gases has been limited by the absence of certified gas standards. Many factors are involved in the inaccuracies of primary gas standards, including gas cylinder materials, blending of gases, analytical methods, and reference standards. Because of these inaccuracies and low industrial demand for certified gases, no standard reference materials were previously available. During FY86, the Gas Standards Evaluation Project undertook to investigate typical specialty gas industry standards and determine the specifications and practices required to produce reliable gas standards for NSTL. The result of this study is a new method for verifying the accuracy of calibration gas standards. National Bureau of Standards approval and acceptance of this method is expected during FY87.

TECHNOLOGY DEVELOPMENT AND UTILIZATION PROGRAMS

Analysis of Volatile Hydrocarbons

Knowledge of the potential presence of contaminating volatile and semivolatile organics and their concentration and source is crucial to NSTL's SSME test operations. SSME testing requires a high-pressure gas facility with a pipeline distribution network for hydrogen, helium, nitrogen, and missile-grade air. The significance of the engine test is potentially complicated by possible organic contamination buildup from a chemically and physically dynamic system that has been in service for more than 20 years. Age and the adverse effect of undetected contamination can eventually lead to material degradation and finally system failure. The purpose of this study was to investigate the sources and degree of contamination present and to identify the methods required for monitoring volatile organics associated with the online gas systems at NSTL. Once the contaminant characterization is available, the significance of the contaminants will be reviewed. Contaminant characterization can provide a means to evaluate and minimize system failure at NSTL.

Master Control Panel Lighting System

A study was initiated to identify and/or develop cost-effective, longer-life alternatives to current NSTL SSME test complex control panel indicator lamps. The Engine Test Control Centers utilize 7,264 midget incandescent indicator lamps. The lifetime of each of these lamps averages only 10 weeks, thus resulting in unacceptably expensive lamp replacement costs and a potential for compromise of operational safety. This study resulted in development of two new lighting devices, a long-life incandescent lamp and an ultrabright light-emitting diode (LED). The new lamps have a ten-fold increase in reliability, with an average projected lifetime of 2 years. Lamp replacement costs will be cut by an average of 84%. The new LED consists of six LED junctions mounted on a single substrate. The ultrabright output of the LED provides positive recognition at a glance from across the control room. The LED reliability will virtually eliminate lamp replacement for the next 11 years. Two thirds of NSTL's indicator lamps will be replaced by the new LED, with the remaining one third to be replaced by the new long-life incandescent lamps.

TECHNOLOGY UTILIZATION

The NSTL Technology Utilization Program has continued to develop a broad-based technical emphasis with a balanced focus on national, State, and local efforts with public and private sector participants.

Mississippi Technology Transfer Office

During FY86, a major Technology Utilization effort was assisting the State of Mississippi in establishing the office of a senior representative at NSTL to represent the Governor and the State in identifying and developing opportunities for technology transfer. The mission of the Mississippi Technology Transfer Office (MTTO) is to provide liaison between NSTL, State agencies, and the private sector of Mississippi so appropriate technology can be applied for the well-being of the State.

The State made a strong commitment to its participation in technology transfer activities by funding the construction of a $3.5 million Mississippi Technology Transfer Building at NSTL. Special permission was received by NASA from the U.S. Congress to accept this building as a gift from the State. The 51,000-square-foot facility (pictured in the architect's rendering, Figure 25) was nearing the 60% completion mark at the end of FY86. This building, when completed in the spring of 1987, will facilitate the location of new programs and organizations at NSTL which otherwise could not have occurred due to building space limitations. Immediate benefits to the State will be an increase in "high tech" employment and an increased tax base. A portion of the building will remain under State control; it will house the MTTO and provide short-term space for incubator businesses and State agencies working with NASA and other Government agencies on technology transfer projects at NSTL. This will give the State of Mississippi direct access to Federal technology residing with NASA/NSTL and other Federal agencies in residence at NSTL.

The MTTO has developed a five-point plan for what the State must accomplish at NSTL to help infuse technology into the State and improve economic development:

- Encourage other agencies and organizations to locate at NSTL on a time-limited basis to acquire and adapt NASA technology and develop solutions to public problems, or to commercialize a product or service that establishes or expands an existing business enterprise.
- Conduct Statewide efforts to inventory Mississippi

Figure 25. Artist's Rendering of New Mississippi Technology Transfer Building

government and industry problems that may be resolved through technology.

- Utilize top university personnel to inventory beneficial NASA and other Federal technologies for exploitation in addressing problems.

- Serve as a focal point to assist the NSTL technology transfer efforts by brokering technology, making appropriate matches, and conducting follow-through activities.

- Develop a reimbursable mechanism for State agencies to access NSTL support contractor resources for technology transfer services which are not commercially available, thus allowing quick access to Federal facilities and expertise for problem solving.

Another major participant in technology transfer activities has been the Institute for Technology Development (ITD), a not-for-profit Mississippi corporation initially established with Federal, State, and private funds to unite Mississippi's fragmented technology resources for economic development and technology transfer of leading-edge research.

The NSTL Technology Utilization Officer is working closely with the ITD to identify opportunities for NASA technology to be adapted and applied to the expansion of small businesses. The ITD represents an expanding network that interfaces extensively with industry on a State and national basis to bring new technology into the U.S. industrial base. (Another Division of ITD at NSTL is the Space Remote Sensing Center, discussed in the Commercial Programs Section of this report.)

Environmental Systems

The Environmental Systems Laboratory at NSTL has become one of the most widely recognized laboratories in the world in the use of aquatic and terrestrial plants for water and industrial pollution abatement. This biotechnology has evolved over the past 15 years from research activities performed as part of the NSTL environmental management mission integrated with numerous technology utilization projects.

The Laboratory performs research in areas such as the utilization of higher plants and microorganisms for treating domestic sewage and toxic industrial waste, recycling sewage to potable water, and removing trace organic chemicals from the air inside closed facilities, such as energy efficient homes, office buildings, and industrial facilities. The following programs evolved from local and national problems whose solutions were addressed through the adaptation of NASA/NSTL technologies in these areas.

Foliage Plants for Removing Indoor Air Pollutants

A significant indoor air pollution problem exists in structures such as energy efficient homes and space habitats due to outgassing of building materials, furnishings, and electronic components. The accumulation of gaseous toxic substances in the air of poorly ventilated places has been known for many years, but only in recent years recognized as a potential indoor health hazard. Recent research has demonstrated that common houseplants, such as the spider plant, philodendron, and golden pothos, have great potential for removing indoor pollutants from such facilities. The ability of these plants to remove formaldehyde and benzene has been demonstrated at NSTL in test chambers. Data are now available to begin scale-up for studying these two chemicals in room-sized habitats. Studies are continuing to evaluate other organics that are indoor air pollutants. During the past year, hundreds of inquiries have been received relating to indoor air pollution problems. Results achieved to date have been published and disseminated.

TECHNOLOGY DEVELOPMENT AND UTILIZATION PROGRAMS

Bioregeneration of Activated Carbon

NASA scientists from NSTL are continuing to consult with the City of San Diego, California, on an innovative project to biologically upgrade domestic waste water to potable water. The last component in the treatment train prior to final disinfection is proposed to be activated carbon; but thermal regeneration of carbon is very expensive. NSTL is performing research on the biodegradation by increasing the effective concentrations of organics available to the microorganisms. Current efforts have addressed determining minimum regeneration times and conditions necessary to sustain a self-regenerating carbon purification system. This effort is expected to continue for several more years to refine the process.

Biological Cleanup of a Hazardous Waste Site

NASA/NSTL environmental scientists are also consulting with the State of Florida on the potential of using biodegradation as the primary means of cleaning up a hazardous waste site near Pensacola. NSTL has developed a work plan for the cleanup activity that utilizes the biodegradation in soil of the priority pollutants contaminating the site. Several strains of adapted microorganisms are showing exceptional promise for degrading toxic chemicals under field conditions. This effort will continue to trace the effects of these techniques over time for completing site cleanup.

Magnetic Resonance Imaging

The NSTL Earth Resources Laboratory is in the second year of an Applications Engineering Project with the Kennedy Space Center and NSTL Technology Utilization Offices. The objective is to assist the medical community in most effectively utilizing data acquired by magnetic resonance imaging (MRI).

FY86 efforts were concentrated on completing a thorough understanding of the MRI data structures, so subsequent phases of the work can be done with maximum efficiency and effectiveness. Both long- and short-wavelength features are being studied. Utilizing areas manually classified as being anatomically identical, and images of a uniform synthetic material ("phantoms"), two-dimensional polynomials of various degrees were created using ELAS module TREN. The images formed from the original data, the models, and residuals were studied. It was found that a polynomial of Order 2 describes the vast bulk of long-wavelength, target-independent variation. This is an extension into two dimensions of the previous one-dimensional work. The resulting model image forms either a saddle or a dome. Variations of the model's geometry are apparently not consistent with any known data acquisition parameter. Examination of the residuals from the phantoms showed that the true model cannot be described by a simple polynomial. The current interpretation is that the phenomenon is largely, but not completely, a function of distance to the MRI antenna. Such knowledge should permit effective removal of the artifact.

Short-wavelength contrasts, related to both variation between classes and within classes, are being examined using a new technique developed at ERL. This research employs a stepwise clustering routine. Starting with the center pixel of a 7- by 7-pixel window, the adjacent pixel most like the center pixel is identified and added to the cluster. All pixels contiguous to either of these two pixels are examined. The one most like the average of the cluster is added to the cluster. This process continues until a predetermined number of pixels have been aggregated. The mean and standard deviation of each cluster are plotted as each new pixel is added. The ERL theory predicts that the behavior of this plot can be used as a key to spatially/spectrally meaningful classifications.

Major progress is also being made in developing the required Fourier analysis capabilities. As the original data are actually collected in the frequency domain, rather than the spatial domain, examining this aspect of the imagery is important. Indeed, one defect in some of the images is probably traceable to problems in handling the phase information in the original transformation from the frequency to spatial domain.

APPENDIX

- Sources of Additional Information
- FY86 NSTL Publications
- Other Literature Cited

APPENDIX

APPENDIX

Sources of Additional Information

For additional copies of this Report, contact:

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NASA/NSTL
NSTL, MS 39529
(601) 688-1660
FTS 494-1660

For additional information on the topics discussed, contact the principal authors listed below.

REMOTE SENSING RESEARCH

- Calibrated Airborne Multispectral Scanner—J. E. Anderson, 688-1909
- Airborne Bathymetric System Scanner—J. E. Anderson, 688-1909
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COMMERCIAL PROGRAMS

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  - Ecological Stratification of Tropical Forest Communities—S. A. Sader, 688-1915
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- Earth Resources Laboratory Applications Software
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  - Project Example—NSTL AIM Training Project—B. G. Junkin, 688-1926
  - NASA Guidelines and Considerations—B. G. Junkin, 688-1926
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  - GH_2 Boil-Off Recovery—H. A. Moffitt, 688-2278
  - GH_2 Personal Detector—H. A. Moffitt, 688-2278
  - Gas Analysis Standards—H. L. Watts, 688-1651
  - Analysis of Volatile Hydrocarbons—H. L. Watts, 688-1651
  - Master Control Panel Lighting System—H. A. Moffitt, 688-2278
- Technology Utilization—R. M. Barlow, 688-1929
  - Mississippi Technology Transfer Office—R. M. Barlow, 688-1929
  - Environmental Systems—B. C. Wolverton, 688-3155
    - Foliage Plants for Removing Indoor Air Pollutants—B. C. Wolverton, 688-3155
    - Bioregeneration of Activated Carbon—B. C. Wolverton, 688-3155
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